DUCTILE IRON
The essentials of gating and risering system design
Revised in 2000
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOREWORD</td>
<td>4</td>
</tr>
<tr>
<td>1.0 GATING SYSTEM DESIGN</td>
<td>6</td>
</tr>
<tr>
<td>1.1 Requirements</td>
<td>6</td>
</tr>
<tr>
<td>1.2 Essential Components</td>
<td>6</td>
</tr>
<tr>
<td>1.3 Planning</td>
<td>6</td>
</tr>
<tr>
<td>1.4 The Role of “Choke”</td>
<td>6</td>
</tr>
<tr>
<td>1.5 Selection of Gating System Type</td>
<td>7</td>
</tr>
<tr>
<td>1.6 Friction</td>
<td>7</td>
</tr>
<tr>
<td>1.7 Pouring Time</td>
<td>8</td>
</tr>
<tr>
<td>1.8 Choke Cross Sectional Area</td>
<td>8</td>
</tr>
<tr>
<td>1.9 Choke Configuration</td>
<td>9</td>
</tr>
<tr>
<td>1.10 Sprue Design</td>
<td>11</td>
</tr>
<tr>
<td>1.11 Runner Bar</td>
<td>12</td>
</tr>
<tr>
<td>1.12 Gate Connection</td>
<td>13</td>
</tr>
<tr>
<td>1.13 Pouring Basin and Sprue Well</td>
<td>13</td>
</tr>
<tr>
<td>1.14 Common Defects Relating to Poor Gating System Design</td>
<td>14</td>
</tr>
<tr>
<td>1.15 Case History</td>
<td>15</td>
</tr>
<tr>
<td>1.16 Molten Metal Filtration</td>
<td>17</td>
</tr>
<tr>
<td>2.0 RISERING SYSTEM DESIGN</td>
<td>19</td>
</tr>
<tr>
<td>2.1 Objectives</td>
<td>20</td>
</tr>
<tr>
<td>2.2 Essential Components</td>
<td>20</td>
</tr>
<tr>
<td>2.3 The Following are Suggested by Research and Supported by Industrial Experience</td>
<td>20</td>
</tr>
<tr>
<td>2.4 Typical Volume Change Patterns</td>
<td>21</td>
</tr>
<tr>
<td>2.5 Planning</td>
<td>21</td>
</tr>
<tr>
<td>2.6 Cooling Rate</td>
<td>22</td>
</tr>
<tr>
<td>2.7 Mould Quality</td>
<td>23</td>
</tr>
<tr>
<td>2.8 Liquid Iron Processing</td>
<td>23</td>
</tr>
<tr>
<td>2.9 Selection of Risering Method</td>
<td>24</td>
</tr>
<tr>
<td>2.10 Pressure Control Risering</td>
<td>25</td>
</tr>
<tr>
<td>2.11 Bottle Riser</td>
<td>28</td>
</tr>
<tr>
<td>2.12 Riserless Design</td>
<td>30</td>
</tr>
<tr>
<td>2.13 Directly Applied Risering Design (DAR)</td>
<td>30</td>
</tr>
<tr>
<td>2.14 Selection of Pouring Temperature Based on Risering Method</td>
<td>32</td>
</tr>
<tr>
<td>2.15 Pressure Control Risering &amp; Bottle Risering Case Histories</td>
<td>33-37, 41-43</td>
</tr>
<tr>
<td>2.16 Metallurgical Quality Control</td>
<td>38</td>
</tr>
<tr>
<td>2.17 Methods to measure Metal Quality</td>
<td>38</td>
</tr>
<tr>
<td>2.18 Other Risering Aids</td>
<td>39</td>
</tr>
<tr>
<td>2.19 Chills</td>
<td>40</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td>44</td>
</tr>
</tbody>
</table>
The importance of casting soundness and production economy, as influenced by gating and risering practice, has been recognized for many years by RIT’s producers of high purity iron QIT - Fer et Titane Inc. (QIT) and Richards Bay Iron and Titanium (Pty) Limited (RBIT). Indeed, it can be accurately described as being a RIT tradition of interest and involvement in this area of castings production. The pioneer in this work was Dr. Stephen I. Karsay and his book entitled “Ductile Iron III – Gating and Risering” has formed the basis for this present seminar/lecture notes book.

In addition to Karsay’s groundwork, a number of other RIT technical service personnel have made valuable contributions towards RIT’s present approach to the task of gating and risering. True to tradition, RIT has closely followed the results and experiences of others working in this field and, where appropriate, has incorporated some of these into its presentations on the subject.

This set of seminar/lecture notes forms the basis for gating and risering presentations which are regularly given around the world to groups of foundrymen at seminars and meetings organized either by RIT and its agents or in conjunction with foundry organizations. The notes are not intended to be a comprehensive treatment of the subject but rather to give the essential features of RIT’s approach in a form, that is easy to use and apply. For those who require a more detailed, in depth, treatment of the subject, see the bibliography. RIT is indebted to the foundries and foundrymen who have contributed in many ways over the years during the continuing quest to arrive at a generally acceptable and successful approach to the task of gating and risering Ductile Iron castings.

RIT makes no claim to “have discovered the ultimate formulae”, but suggests that these notes provide a sensible and logical approach to a problem which daily confronts foundrymen – namely, the economic production of clean, sound Ductile Iron castings.

RIT has made every reasonable effort to ensure that the data presented accurately represents the information contained in the many sources from which it was obtained and, when necessary, attempts have been made to reconcile data from different sources which do not agree. Therefore RIT believes that all information given is accurate and is provided in good faith, but without any warranty, either express or implied. This book is protected by copyright and no part of it can be reproduced, stored in a retrieval system or transmitted in any form or by any means without the prior written permission of Rio Tinto Iron & Titanium Inc.

Copyright 2000 by Rio Tinto Iron & Titanium Inc.
Section one

Gating System Design

Please note:
The reader should note that the risering of a casting must be done before the gating system is designed or calculations made.
1.0 GATING SYSTEM DESIGN

1.1 Requirements:
- Fast pouring to: Minimize temperature loss during mould filling.
  Minimize metallurgical “fade”.
  Minimize oxidation.
- Clean pouring to: Avoid slag (dross) generation during pouring.
  Screen out slag from first iron poured into mould.
- Economic Design: Maximize casting yield.

1.2 Essential Components:
All components shown are necessary to minimize occurrence of slag defects.

1.3 Planning:
Generate a basic layout by considering: optimum space utilization for castings; chosen risering method; place parting to minimize need for cores; castings located in cope, fill quietly; simple, symmetrical system; identical gating and risering for identical castings; use one riser for more than one casting if possible; LEAVE ROOM ON PLATE FOR ADEQUATE GATING AND RISERING SYSTEM.

Detailed design follows planning.

1.4 The Role of “Choke”:
- Definition: Choke is that cross sectional area in a gating system which determines mould filling time.
- There are two “correct” locations for the choke, hence two basic gating system types:

Choke located at junction of runner and gate in a simple GATE-RUNNER (pressurized) system.

Choke located at junction of sprue and runner in a simple SPRUE-RUNNER (non-pressurized) system.
1.5 Selection of Gating System Type:
- In a GATE-RUNNER system castings are choked individually by one or more chokes or gates. With a SPRUE-RUNNER system it is possible for several castings to share a common choke.
- Use SPRUE-RUNNER system for large number of small castings in one mould where it is impractical to choke the castings individually – where choke dimensions are very small – very demanding on moulding technique and pouring temperature.
- Use GATE-RUNNER system on most other occasions.
- Features of GATE-RUNNER and SPRUE-RUNNER SYSTEMS can be combined to form a HYBRID system. This is normally used where a complicated network of runners is required to deliver iron to casting cavities.

1.6 Friction:
- Not all potential energy of liquid at top of sprue is converted to mechanical energy at casting cavity.
- Some potential energy lost to friction (heat) as liquid moves against mould wall and liquid moves against liquid.
- Energy loss due to friction extends mould filling time and must be taken into account when calculating choke cross sectional area and pouring time.
- Energy loss estimated by selecting value of “f_r”, frictional loss factor.

- for thin “plates”, $f_r \rightarrow 0.2$
- for heavy “cubes”, $f_r \rightarrow 0.8$
1.7 Pouring Time:

- As fast as possible consistent with human ability and production routine.
- Recommended pouring times:

\[ t \text{ sec} = \sqrt{W \text{ lb}} \]

\( W = \text{weight of castings + risers} \)

1.8 Choke Cross Sectional Area \((A_c)\):

- Select fastest practicable pouring time \(t_r\) (sec.) for total poured weight (section 1.7).
- Select suitable “\(f_r\)” value. (Section 1.6)
- Determine total poured volume/choke \(V\) (in.\(^3\), cm.\(^3\))
- \(V\) is volume of all castings plus risers, downstream of a particular choke.
- Volume = weight/density. For liquid iron, density = 0.25 lb/in\(^3\) or 0.007 Kg/cm\(^3\).
- Determine effective ferrostatic head in sprue \(H\) (in., cm.)
- Determine height of casting in cope \(b\) (in., cm.)
- From Torricelli, velocity of iron stream at choke is,

\[ v_c = f_r \sqrt{2gH} \]

- When casting located entirely in drag,

\[ A_c = \frac{V_D}{t_r f_r \sqrt{2gH}} (b = 0) \]

\(g = \text{acceleration of gravity} = 386 \text{ in/sec}^2 \text{ or } 981 \text{ cm/sec}^2\)

- When casting located entirely in cope,

\[ A_c = \frac{1.5 (b) v_c}{f_r t_r \sqrt{2g} \left[ \sqrt{H^3} - \sqrt{(H - b)^3} \right]} \]

- When casting located in cope and drag,

\[ A_c = \frac{1}{f_r t_r \sqrt{2g}} \left[ \frac{V_D}{\sqrt{H}} + 1.5 (b) \frac{v_c}{\sqrt{H^3} - \sqrt{(H - b)^3}} \right] \]
- A reasonably accurate guide to suitable $A_c$ can be selected from these plots:

![Graph showing plot data]

- Plot data is based on average cope heights which will vary from foundry to foundry. In the majority of cases this introduces negligible error.

- Mould filling process should be timed and if actual filling time is significantly different from selected filling time, choke should be redesigned according to above equations.

1.9 **Choke Configuration:**

**GATE-RUNNER:** The total choke cross sectional area is the sum of individual gate cross sectional areas:

- Total choke = $A_c = A_1 + A_2 + \ldots A_n$
- $A_c$ chosen according to casting weight. For multiple chokes ($A_1, A_2$), individual choke cross sectional area chosen according to $(\text{weight of castings} + \text{risers})$
  \[
  \frac{1}{\text{number of chokes}}
  \]
  from section 1.8.

- Individual gate dimensions: let choke dimensions = 4a wide x a thick. $4a^2 = A_1 = A_2$ hence, a, 4a.
• Total choke = \( A_{c1} + A_{c2} \)
• \( A_{c1} = A_1 + A_4; A_{c2} = A_2 + A_3 \)
• \( A_1, A_2, A_3, A_4 \), chosen according to casting weight (section 1.8)
• Individual gate dimensions:
  \( A_1 = A_2 = A_3 = A_4 = 4a \) (a), as before.

• **SPRUE-RUNNER**: The total choke cross sectional area is the sum of individual choke cross sectional areas downstream of the sprue:
  \( A_c \) chosen according to \( W_1 + W_2 + W_3 + \ldots + W_N \) (section 1.8)
  • Total choke, \( A_c = 4a \) (a)
  • \( a = \) choke thickness; \( 4a = \) choke width

Note: when using filters the design of the runner and gates can be changed (volume reduced) since the choke will be at the filter.
• $A_{c1}$ chosen according to $W_1 + W_2 + W_3 + W_4 + W_5 + W_6$
• $A_{c2}$ chosen according to $W_7 + W_8 + W_9 + W_{10} + W_{11} + W_{12} + W_{13}$
• $A_{c1} = 4a (a) = A_{c2}$ hence a, 4a

1.10 Sprue Design:
• Ensure sprue does not act as choke.
• Design according to $A_s = A_c \sqrt{\frac{H}{h}}$ (minimum)
• $A_c = \text{sum of all choke cross sectional areas}$.

• This design holds for upward taper, downward taper and parallel sprues. $A_s$ relates to the smallest cross section in a tapered sprue. In the case of downward tapered sprues, “h” is measured to the smallest cross section of the sprue, which normally is at the runner / sprue junction.

• Avoid use of standard sprue diameter.
  If you must use standard sprue diameter, design according to
  $A_c = A_s \sqrt{\frac{h}{H}}$ (maximum)

This invariably slows down mould filling incurring higher temperature loss and increased risk of casting defects.
1.11 Runner Bar:

Exists to reduce flow velocity of iron stream thus allowing slag particles to float out of iron stream.

- Avoid use of curved runners.
- Avoid use of stepped runners.

- **GATE-RUNNER**: use tall narrow runners with cross sectional area ($A_R$) about 2 to 4 times total cross sectional area of gates attached to runner.

$$A_R = 2a \times a = 3 \times (A_c)$$

- Use tapered extension or where space does not permit, use drag well

- Gate location should not be too close to sprue or runner bar end

- Branch gates at 90° to runner and don’t stagger gates on opposite sides of runner.

- **SPRUE-RUNNER**: Square runner cross section at choke end tapering to rectangular section towards end of runner.

- Taper determined by making cross sectional area just beyond last gate, equal to choke cross sectional area $C$. 
1.12 Gate Connection:
GATE-RUNNER: always connect to side of runner

- Ensure that bottom of runner and bottom of gate(s) are in the same horizontal plane.
- SPRUE-RUNNER: Place runner in drag, gates in cope.
- Total area of gate overlap should be slightly more than choke cross sectional area. (+ 10%)
- Gates overlap top of runner by slightly more than gate thickness.
- Always connect gate to top of runner.

1.13 Pouring Basin and Sprue Well:
Worst shape for pouring basin is conical – much splashing at start of pour.
- Best shape is “sump” where $L = 2 \times W$
- Sprue well required to avoid aspiration at sprue-runner junction. Shape square or rectangular, flat bottom.
1.14 Common Defects Relating to Poor Gating System Design:

- GAS-HOLES at or near cope surface.
- Poor design allows slag, metallic oxides (M0, major slag component) to enter casting cavity.
- Oxides react with carbon dissolved in iron.
- \[ M0 + C = C0 + M \]
- C0 bubble floats to cope surface or is trapped under core.
- Remedy by examining gating system for violations or simple rules presented previously.

- MAGNESIUM SILICATE defects act as cracks when located at or near casting surfaces. These drastically reduce dynamic mechanical properties (impact, fatigue, fracture toughness).
- Most common cause is use of too small a sprue for selected choke. (Refer to section 1.10.)
- Low pouring temperature can increase problem.
- LAP TYPE defects and “ELEPHANT SKIN”.

- Extreme case of magnesium silicate contamination where several liquid streams entering casting cavity are covered with magnesium silicate film. When separate streams meet, the surface films will not allow complete fusion.

- Check sprue size (section 1.10).

- Check design of gating system for components likely to cause undue turbulence.

- True cold lap defects are not very common in ductile and grey iron castings.

- LUSTROUS CARBON defects occur as “wrinkles” or “peel” which are partially detached from the cast surface.

- Occurrence due to excessive carbonaceous matter in moulding sand. Defect encouraged by slow mould filling.

- Remedy by decreasing pouring time (section 1.7) and adjusting composition of moulding sand.

1.15 Case History:

- High incidence of scrap castings due to lap type defects and cope surface “peel” (Ductile iron castings).

- Micro section showed gross lap type defect containing magnesium silicate film. Cope surface “peel” typical of lustrous carbon defect.

- Examination of original gating showed a gate-runner system, but without correctly designed gates.
• Implication: The first iron poured contained relatively high concentration of slags. This is unavoidable in spite of meticulous ladle practice, skimming, etc. Since the runner leads directly to the riser (no gates) the first, slag rich iron poured, entered the riser and subsequently the casting cavity. (See next page).

• Implication: The “choke” in the original system is the smallest cross section between the sprue and the casting cavity, i.e. the runner cross section. This violates the design criteria:

\[ A_s \geq A_c \sqrt{\frac{H}{h}} \quad \text{(here } A_c = A_R) \]

leading to generation of magnesium silicate slag in the gating system, extended pouring time, high temperature loss.

• Redesign: Total poured weight (casting + riser) = \((15 + 2) = 17 \text{ lb (7.73 kg)}\).

• Gate runner system will be used.

• Casting located 50% in drag, 50% in cope.

• \( f_r = 0.4 \) (section 1.6)

• Recommended pouring time, \( t = 4 \text{ secs. (section 1.7)} \)

• Ferrostatic head in sprue (approx. cope height), \( H = 8 \text{ in. (20.3 cm)} \)

• Pouring basin depth, \( h = 3 \text{ in. (7.62 cm)} \)

• Height of casting in cope, \( b = 2 \text{ in. (5.1 cm)} \)

• Total choke cross sectional area, (section 1.8), for casting located in cope and drag:

• for given conditions, selected \( A_c \) value from plot on page 9 is \( A_c = 0.37 \text{ in.}^2 (2.38 \text{ cm}^2) \)

• Sprue design (section 1.10),

\[ A_s \geq A_c \sqrt{\frac{H}{h}} = 0.37 \left(\frac{8}{3}\right) 0.5 \]

\[ A_s = 0.60 \text{ in.}^2 (3.88 \text{ cm}^2) \]

hence \( D_s = 0.88 \text{ in.} \)

minimum sprue diameter = 0.88 in. (2.24 cm)

• Individual choke dimensions, (section 1.9)

\[ A_c = 0.37 \text{ in.}^2 \text{ and gate dimensions are } 4a \times a \text{ since there is one gate,} \]

\[ 4a \times a = 0.37 \text{ in.}^2 (2.38 \text{ cm}^2) \]

hence \( a = 0.30 \text{ in. (7.1 cm)} \)

\[ 4a = 1.22 \text{ in. (3.1 cm)} \]

• Runner area, (section 1.11),

\[ 2a^2 = 3(0.37) \quad a = 0.75 \quad 2a = 1.49 \text{ in.} \]

\[ 3(2.38 \text{ cm}) \quad (1.91 \text{ cm}) \quad (3.78 \text{ cm}) \]

• Due to space restrictions on the pattern plate, the riser was moved to the opposite side of the casting since the runner, gate and riser could not all be accommodated on one side.

• In the re-design, the riser is “cold”, with a exothermic sleeve whereas the original design showed a “hot” riser. This appears not to be detrimental to casting integrity. Probably because the redesigned system permits faster filling of the mould hence less iron temperatures loss during mould filling.
• The re-design reduced scrap levels thereby improving casting yield from 16% to 67%.

\[
\text{casting yield} = \frac{\text{weight of good castings sold}}{\text{weight of iron poured}}
\]

55% scrap slag and lustrous carbon
72% pattern yield

Before

Exothermic riser

< 5% scrap
70% pattern yield

After

• Alternative system designs could include filters and other types of risers to further improve yield.

1.16 Molten Metal Filtration

The use of molten metal filters is becoming established practice for an increasing number of foundries to improve casting quality, yield, machinability and properties. With this growth in use there is a need for an increased technical understanding of filtering technology in general. It is not enough for a filter to just have good filtration efficiency. It must also have a high and consistent flow rate, good strength, high capacity, good dimensional accuracy and low cost. Some of these parameters are in conflict with each other, for example if a filter has a very large capacity, the filtration efficiency may be compromised. The most effective filters are therefore ones that have been engineered to give the optimum performance over all of these parameters.
There are several established filter technologies presently on the market. These include strainer cores, woven cloth or mesh, and ceramic tile filters. Ceramic tile filters are generally considered to be the most effective and used for smaller molds & pours. The most popular of these are pressed cellular, extruded cellular and foam filters. Pressed cellular are generally characterized by their round cells, extruded filters generally have square cells, whilst foam filters have a random dodecahedron type structure.

- Filtration Efficiency is important to remove slag and dross from the iron to prevent them from entering the mold cavity.

- Metal Capacity must be adequate for the casting but it should also be consistent. The capacity should not vary from filter to filter. This may lead to premature blockage in some cases.

- Flow Rate must be high and consistent. Wide variations in flow rate may in some cases, lead to mold fill problems, or a requirement to use a larger filter thereby increasing cost and decreasing yield.

- Dimensional Accuracy is important because the filters should fit into their print cavity correctly each time.

- Strength (hot or cold) is important for shipping and handling purposes and so the filter remains intact when molten metal is poured onto it.

Filters do a good job of removing inclusions using a variety of mechanisms. Some types may be more efficient at one mechanism than another. Filters will collect dross particles and inclusions by screening, that are larger than the filter hole or pore size, on their upstream face. These particles are unable to pass through to the casting cavity due to their physical size. Secondly, large dross particles collected on the upstream face during the screening phase will form what is known as a “filter cake”. This cake acts as an efficient filtration media. This mechanism is able to collect particles smaller than the cells of the filter. In ductile iron, it is possible that the mechanism for the removal of micro-inclusions, (<1% of the cell size), is through the formation of “inclusion bridges”. Small eddy currents, formed when the metal stream splits on the active face of the filter, are generated. These eddy currents will encourage small non-metallic particles to make contact with the edges of the cell. As the pour progresses these particles will continue to adhere to each other and will eventually form an “inclusion bridge”.

The use of the filters has increased dramatically in the past 10 years as the cost per unit has decreased while casting wall thickness has been reduced and general quality requirements for castings have increased. However, as always, some experimentation must be done in the foundry to establish proper filter sizes, ladle deslagging practices and pouring temperature ranges so that good casting yield is maintained.
Section two

Risering System Design

Please note:
Risering must be done before gating system can be calculated. Bottle shaped (Heine) risers are now the riser of choice in the majority of systems.
2.0 RISERING SYSTEM DESIGN

2.1 Objectives:
- castings without shrinkage defects
- economic production – maximize casting yield

2.2 Essential Components
- Riser – always “blind” (closed top).
  Riser contact – generally as short as possible. Designed dimensions always measured at the notch.
- Gate – thin and wide for fast freezing (see p. 28).
- Vents – to assist fast mould filling.

Risering System - Definitions

2.3 The Following are Suggested by Research and Supported by Industrial Experience
- Volume change patterns of cooling and solidifying graphitic irons result in net volume increase of iron in the mould.
- The net volume increase can produce liquid pressure in the mould of several hundred p.s.i. (2 MPa).
- This pressure always exceeds the elastic limit of the mould, except for very rigid moulds, leading to mould enlargement and swollen castings, often containing shrinkage defects.
- Green sand moulds are not considered to be rigid in this context.
- Riser function is very sensitive to pouring temperature and pouring time.
- Volume change pattern is not constant but varies according to cooling rate and liquid iron processing route (superheat, charge composition, melting method, inoculation, etc).
- Due to the high pressures experienced by the mould during pouring and solidification, mould halves should be clamped together. Weighting alone is not sufficient.
2.4 Typical Volume Change Patterns
- General volume change pattern for steel, white iron, brass, etc.

- Volume change patterns for graphitic irons.

- Cooling liquid initially contracts then expands. Towards the end of solidification, last remaining liquid solidifies with contraction.

- Shape of volume change pattern influenced by cooling rate and by changes in liquid iron processing. This directly affects the extent of contraction and expansion.

2.5 Planning
The detailed design principles will be presented in the following order:
- Determine significant modulus of the castings ($M_S$).
- Evaluate mould and iron quality, then select appropriate risering method.
- Determine corresponding liquid transfer modulus ($M_N$) and number of risers required for each casting.
- Select riser type and compute dimensions ($M_R$).
- Select riser contact (neck) type and compute dimensions.
- Check that available feed volume in riser(s) is sufficient for casting's requirements.
- Select pouring temperature based on selected risering method.
2.6 Cooling Rate

- Casting weight or wall thickness not sufficiently accurate to describe cooling rate.
- Simple shapes: cube, plate, bar etc, all 1 inch (25 mm) thick but all cool at different rates.
- Use modulus (M) to describe cooling.
- Modulus = \[
\frac{\text{volume}}{\text{effective cooling surface area}}
\]

• More complicated shapes should be broken down into simple shapes and the moduli of the individual simple shapes, determined.

Note in the example that the connecting surfaces between adjacent segments are not considered to contribute to cooling (variable “c” below).

Where:
\[
V = \text{total casting volume.}
\]
\[
\text{CSA} = \text{total cooling surface area of the casting}
\]

**Example for the calculation of Modulus**

1. Cube
   \[
   M = \frac{a}{6}
   \]
   Horizontal dimensions are at least 5-times larger than “a”

2. Plate
   \[
   M = \frac{b}{2}
   \]
   \(b\) (length > 5b)

3. Square Bar
   \[
   M = \frac{d}{4}
   \]
   (length > 5d)

4. Round Bar
   \[
   M = \frac{ef}{2e + 2f}
   \]
   (length > 5e)

5. Rectangular Bar
   \[
   M = \frac{ef}{2e + 2f}
   \]
   (f < 5e)

- all dimensions in cm

\[
M_1 = \frac{5 \cdot 2.5}{12.5} = 1.0 \text{ cm}
\]
\[
M_2 = \frac{5 \cdot 3}{10} = 1.5 \text{ cm}
\]
\[
M_3 = \frac{5 \cdot 4}{11} = 1.8 \text{ cm}
\]

Significant Modulus = \(M_3 = 1.8 \text{ cm}\)

Note: See example on page 36.
• When hollow sections are involved, the cooling effect of cores may be approximated as shown.

ADJUSTMENTS TO THE COOLING SURFACE AREA

If \( d < \frac{1}{3} \, D \), ASSUME 0% COOLING FROM CORE

If \( d > \frac{1}{3} \, D \) and \( d < \frac{2}{3} \, D \), ASSUME 50% COOLING FROM CORE

If \( d > \frac{2}{3} \, D \), ASSUME 100% COOLING FROM CORE

2.7 Mould Quality
• Objective is to avoid enlargement of the mould from high liquid pressures exerted by the cooling and solidifying graphitic iron.

• Green sand and shell moulds will not withstand the solidification pressure.

• Chemically bonded sand moulds will resist solidification pressure if they are properly prepared. This requires mechanical compaction of sand during mould preparation and adequate curing.

• Cement sand and dry sand moulds will normally withstand the iron solidification pressure.

2.8 Liquid Iron Processing
• All aspects of iron processing have some influence on the magnitude of volume change during cooling and solidification, hence the shrinkage characteristics of the iron.

• Some of the factors which increase shrinkage tendency:
  • high melt superheat temperatures
  • long holding times in the furnace
  • high proportion of foundry return scrap or steel scrap in the charge
  • presence of carbide stabilizing elements in melt chemistry (including high Mg)
  • variable carbon equivalent of the iron
  • inadequate inoculation.

• Combined effect of these (and other) process variables can be assessed, very approximately, by measuring nodule count of standard test piece (Nodule count increases with faster cooling).

• Irons which show low tendency to shrinkage always seem to show low tendency to form as-cast carbides i.e. they graphitise well. Such irons are said to possess good “metallurgical quality”.

• The presence of any type of carbides in the as-cast structure should be considered as an indication that the iron has poor metallurgical quality. Consequently problems with shrinkage defects should be expected.
• Plot shows range of expected nodule counts for good metallurgical quality ductile irons in dependance of modulus (cooling rate).

• For example, a 1 in (25 mm) ‘Y’ block has a modulus of 0.33 in (8 mm). For good metallurgical quality iron, range of nodule counts is 140-280/mm.

• See also 2.16 and 2.17.

2.9 Selection of Risering Method

• CONVENTIONAL RISERING – The test bar blank or ‘Y’ block is one example. Use of a large (open) riser encourages directional solidification ensuring defects appear in the riser not the test bar blank (parallel sided portion).

• Problem with conventional risering is low yield. In this example, about 23%. Not economical.

• APPLIED RISERING –

Use this “family tree” to select risering method for your production conditions.
• Selection based on mould strength and casting modulus.

• Methods take advantage of the fact that graphitic irons expand during cooling, unlike steel, white iron, malleable iron etc.

• WEAK MOULD: Green sand, shell, non-compacted chemically bonded sand.

• STRONG MOULD: Well compacted chemically bonded sand, cement sand, dry sand, permanent mould.

• There are three basic applied risering methods:
  • pressure control risering (PCR) or bottle riser
  • directly applied risering (DAR)
  • riserless

• Application of each method:
  • when mould is weak and casting modulus is greater than 0.16 in. (4 mm) use PCR.
  • when mould is strong and casting modulus is less than 1.0 in. (25 mm) or when mould is weak and casting modulus is less than 0.16 in. (4 mm) use DAR.
  • when mould is strong and casting modulus is greater than 1.0 in. (25 mm) use RISERLESS.

2.10 Pressure Control Risering

• Most green sand and shell moulded castings should be risered by this method.

• Objective is to control the pressure generated during cooling and solidification, between a minimum pressure level, which will prevent the occurrence of secondary contraction defects and a maximum level, at which the mould will enlarge.

  [Diagram showing pressure control risering]

  • Principles of PCR (necks not used to simplify):
    A. after pouring completed, liquid contracts.
    B. riser compensates for liquid contraction.
    C. when expansion starts, mould deformation avoided by pressurized liquid from casting, "bleeding back" to refill the (blind) riser.
• ideally riser should refill just before expansion ceases.
• this puts all remaining liquid under slight positive pressure and prevents secondary shrinkage defect.

• **Design Sequence:**
  • determine casting significant (largest) modulus ($M_S$) (Section 2.6).
  • determine Modulus – Riserneck ($M_N$)
  • determine Modulus – Riser ($M_R$)
  • see Card #3 metric or english.

Card #3

**PRESSURE CONTROL RISERING METHOD**

Relationship between significant modulus ($M_S$), riser-head neck modulus ($M_N$) and riser-head modulus ($M_R$) in pressure-control riser-system design. Includes factor (f). See page 28.

• select blind riser type and compute dimensions.

• Also see section “bottle riser design”.
• main riser dimensions expressed in terms of diameter, $D$; height = $1.5 \times D$ or with neck located in drag riserheight = $1.5 \times D +$ neck height.

• Find riser neck dimension on Card #4 english or metric.
• Round or square necks = $4 \times M_N$
• Rectangular necks = $3 \times M_N + 6 \times M_N$.

<table>
<thead>
<tr>
<th>Riser Neck Modulus ($M_N$) cm</th>
<th>Riser Modulus ($M_R$) cm ($M_R = M_N \times 1.2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>1.5</td>
<td>3.0</td>
</tr>
<tr>
<td>2.0</td>
<td>4.0</td>
</tr>
<tr>
<td>2.5</td>
<td>5.0</td>
</tr>
<tr>
<td>3.0</td>
<td>6.0</td>
</tr>
<tr>
<td>3.5</td>
<td>7.0</td>
</tr>
<tr>
<td>4.0</td>
<td>8.0</td>
</tr>
<tr>
<td>4.5</td>
<td>9.0</td>
</tr>
<tr>
<td>5.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Poor Quality</th>
<th>Good Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td>1.0</td>
</tr>
<tr>
<td>1.0</td>
<td>1.5</td>
</tr>
<tr>
<td>2.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>8.0</td>
<td>8.0</td>
</tr>
<tr>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>10.0</td>
<td>10.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Riser Type</th>
<th>Riser Diameter ($D$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>D = 5.68 Mr</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>D = 4.91 Mr</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>D = 4.53 Mr</td>
<td></td>
</tr>
</tbody>
</table>

Type 1 (contact in cope)  
Type 2 (contact in drag)  
Type 3 (Top Riser)
• Riser neck dimensions are measured at the bottom of the radius between riser and casting.

• Additional notching of the contact may be introduced providing the additional notch depth is not more than one fifth contact thickness.

• Determine volume (weight) of riser(s) for yield and gating system design calculations.

• Only that portion of the riser which is higher than the highest point of the casting to which it is attached, will compensate for liquid contraction in the casting. See Card #5.

• Feeding distance should be assumed to be a maximum of 10 x M_{hi}.
• Determine effective feed volume of riser(s) and check against casting requirements. “X” is the effective riser height. (See Card #5)

• If the effective volume of riser(s) is less than the volume required by the casting(s), larger or multiple risers should be used.

• In order for the PCR system to function correctly, the gating system must be isolated from the casting and riser very soon after mould pouring is complete. This can be achieved by ensuring the gate has a low modulus $M_G$, (fast freezing) compared to the liquid transfer modulus ($M_N$).

• For design purposes, $M_G \leq 0.2 M_N$. If $M_G$ does not satisfy this condition, increase the number of gates but maintain the same total gate cross sectional area. Individual gate dimensions and modulus will be reduced but mould filling time will be unchanged.

### 2.11 Bottle Riser Design

It is very important that a primary shrinkage hole (pipe) is created quickly in a riser, so that the riser can feed metal into the casting. If the liquid metal in the riser is not open to the atmosphere (skins over), the riser will not function. Atmospheric pressure is necessary to push metal into the casting.

The classical riser shape with a rounded or flat top, even with a “v” or a dimple on the top, may not always guarantee that the riser will pipe. Temperature control is also very important with this design, since these risers work well at higher pouring temperatures, but not at low ones.

Ductile Iron tends to form a thin stable skin quite quickly and especially at lower temperatures due to the magnesium content contributing to an oxidized surface layer. Once this skin forms the liquid metal is not open to the atmosphere and a vacuum can be created inside the riser. At this point the riser will not feed at all unless it begins to collapse.

A bottle riser (also known as a “Heine Riser”) has such a small area at the top diameter that it will begin to pipe very quickly. So in order to have sufficient feed metal volume these risers must be taller than classical designs, which were normally 1.5:1 height:diameter. The height to diameter ratio for a bottle riser will vary according to the amount of feed metal required. This is usually taken to be about 4%, which includes a safety factor. This type of riser is also not as dependent upon pouring temperature for it to function. Since this riser is so efficient it can improve the overall yield by as much as 2% or more.
The determination of the riser size for the bottle type riser is very simple. The size is calculated from the significant modulus of the casting and the weight of the casting, which determines the amount of feed metal required. Classical methods use the metal quality and the significant modulus to find the transfer (riser) modulus and then calculating the riser diameter and the feed metal required so that it can be compared to the riser feed metal volume. The riser neck calculations are done the same way for both risering methods. All risers should be blind.

**BOTTLE RISER FORMULAS**

Riser diameter = \(4 \times (M_S) + \) Riser top diameter

Casting feed metal required = 4% of pouring weight

Riser feed volume - determined by riser top diameter and height to diameter ratio. See table. Use tallest riser possible for flask size.

Riser height = H.D ratio x riser top diameter

**EXAMPLE:**

Casting weight = 187 lbs (85 kg)

Cope height = 13 inches (330 mm)

Significant modulus of the casting \( (M_S) = .6 \) in (15 mm)

* Feed metal required = .04 (187 lbs) = 7.5 lbs (3400 g)
* Choose from table a riser with a 2 in (50 mm) top diameter and 5:1 ratio to give 7.6 lbs (3434 g) of feed metal.
* Riser diameter = \(4 \times .6 \) in + 2 in = 4.4 in (110 mm)
* Riser height = 5 x 2 in = 10 in (250 mm)

### FEED METAL TABLE

<table>
<thead>
<tr>
<th>Ratio (Height: Diameter at top)</th>
<th>Top Dia.</th>
<th>Feed Wt.</th>
<th>Top Dia.</th>
<th>Feed Wt.</th>
<th>Top Dia.</th>
<th>Feed Wt.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in (mm)</td>
<td>lbs (g)</td>
<td>in (mm)</td>
<td>lbs (g)</td>
<td>in (mm)</td>
<td>lbs (g)</td>
</tr>
<tr>
<td>8:1</td>
<td>.4 (10)</td>
<td>.10 (44)</td>
<td>.4 (10)</td>
<td>.07 (32)</td>
<td>.4 (10)</td>
<td>.06 (28)</td>
</tr>
<tr>
<td></td>
<td>.8 (20)</td>
<td>.78 (352)</td>
<td>.8 (20)</td>
<td>.58 (264)</td>
<td>.8 (20)</td>
<td>.48 (219)</td>
</tr>
<tr>
<td></td>
<td>1.2 (30)</td>
<td>2.6 (1186)</td>
<td>1.2 (30)</td>
<td>2.0 (890)</td>
<td>1.2 (30)</td>
<td>1.6 (741)</td>
</tr>
<tr>
<td></td>
<td>1.6 (40)</td>
<td>6.2 (2813)</td>
<td>1.6 (40)</td>
<td>4.6 (2110)</td>
<td>1.6 (40)</td>
<td>3.9 (1758)</td>
</tr>
<tr>
<td></td>
<td>2.0 (50)</td>
<td>12.1 (5495)</td>
<td>2.0 (50)</td>
<td>9.1 (4121)</td>
<td>2.0 (50)</td>
<td>7.6 (3434)</td>
</tr>
</tbody>
</table>
2.12 Riserless Design
Principles of Riserless Design:

- Pour at relatively low iron temperature to avoid (primary) liquid contraction.
- Allow the (rigid) mould to contain all the expansion pressure during iron cooling and solidification.

Production conditions necessary for successful riserless design:

- High metallurgical quality of the liquid iron.
- Very rigid moulds. Green sand and shell moulds not strong enough. Chemically bonded sand moulds may be used providing the sand is mechanically compacted before curing. Mould halves must be clamped or bolted together.
- Minimum casting significant modulus of 1.0 in. (25 mm).
- Pouring temperature range 2,320 – 2,460°F (1,270 – 1,350°C).
- Fast pouring. See Card #2.
- Casting cavity should be well vented.
- Casting cope surface depression will occur if pouring temperature not carefully controlled. Remedy may be effected by using a small blind riser on casting cope surface. Riser volume should be about 2% of casting volume.
- Gating system design should follow the rules described in section 1. Providing fast filling is achieved, gate thickness may be as low as 0.4 in. (10 mm) for the minimum pouring temperature of 2,370°F (1,300°C).

2.13 Directly Applied Risering Design (DAR)
Principles of DAR:

- Use a riser, or the gating system, to compensate for liquid contraction.
- Allow the mould to contain all the expansion pressure during iron cooling and solidification.
- Since the design allows compensation for liquid contraction, thinner sections, poured at higher temperatures, can be produced than is possible with riserless design.

Production conditions necessary for successful DAR design:

- Very rigid moulds if casting significant modulus \( (M_s) \) is greater than 0.16 in (4 mm).
- Excellent control of iron pouring temperature which should not vary by more than ± 25°F (± 14°C).
- DAR can be used with weak moulds if \( M_s \leq 0.16 \) in. (4 mm).

Design Sequence for DAR:

- Determine casting significant modulus \( (M_s) \). In contrast to PCR design, \( M_s \) in DAR design may well be the modulus of the smallest segment of the casting, where solidification and expansion begins.
• Select suitable pouring temperature bearing in mind the value of $M_S$.

- Where $M_S \leq 0.16$ in. ($\leq 4$ mm) and the mould is weak, the sprue can be used to compensate for liquid contraction in casting cavity. To achieve this, gate dimensions should be $4 \times 4$ for rectangular section.
  - When $M_S \geq 0.16$ in. (>4 mm) and the mould is strong, a similar arrangement can be used.
- Gate length should be at least 5 times the gate thickness.
- Alternatively, a riser can be used to compensate for liquid contraction in strong moulds when $M_S > 0.16$ in. (>4 mm) (when $M_S$ exceeds 1.0 in. (25 mm) consider using RISERLESS technique). Riser contact (neck) should be constructed according to the $M_S/M_N$ plots on the following page. Riser volume should (obviously) be large enough to satisfy the volume contraction requirements of the casting.

Porosity resulting from secondary shrinkage.

• Select contact modulus value, $M_N$, dependant upon $M_S$ and desired pouring temperature.
  - For round or square contact, contact diameter $= 4 \times 4$ contact side length $= 4 \times 4$.
  - For rectangular contact, short side $= 3 \times 6$ long side $= 6 \times 6$.
2.14 Selection of Pouring Temperature Based on Risering Method

- **PCR**: 2,500 – 2,600°F (1,380 – 1,425°C) to “guarantee” formation of a shrinkage void in the riser during initial liquid cooling.
- **RISERLESS**: 2,320 – 2,460°F (1,270 – 1,350°C) to avoid liquid contraction in the mould.
- **DAR**: Dependent on casting modulus. (see p. 31)
2.15 Pressure Control Risering
Case Histories

ROTOR: Material GGG 40.3; casting weight 26.0 kg; pouring weight 45.6 kg; yield 58%; moulding material, greensand; $M_s$ 1.90 cm; modulus $A/A = 1.30$; modulus $B/B = 1.25$; $f = 0.60$; $M_N$ 1.14; feeder neck = 45/45 mm; $M_R = 1.37$ cm; feeder = 70 mm dia; pouring temperature 1,400°C min; pouring time 11 sec; gate cross-section 6.5 sq cm; photograph by courtesy of Emmenbrücke foundry, Switzerland.

PULLEY WHEEL: Material GGG 40; casting weight 40 kg; pouring weight 65 kg; yield 62%; moulding material, greensand; $M_s$ 1.0 cm; modulus $A/A = 0.70$; $f = 0.80$; $M_N$ 0.80 cm; feeder neck = 32/32 mm; $M_R = 0.96$ cm; feeder = 70 mm dia; pouring time 12 sec; pouring temp. 1,400°C min; gate cross-section 6.0 sq cm; photograph by courtesy of Emmenbrücke foundry, Switzerland.
FRONT WHEEL HUB: Material GGG 40; casting weight: 5.8 + 5.8 = 11.6 kg; pouring weight: 19 kg; yield: 61%; $M_S = 1.0 \text{ cm}; M_R = 0.8 \text{ cm};$ feeder = 50 mm dia; $x = 4.6 \text{ cm}; M_N = 0.66 \text{ cm};$ feeder neck 40 by 20 mm; pouring temperature $1,370/1,420^\circ \text{C};$ gate area 2.64 sq cm; sprue area 4.5 sq cm; produced on a Disamatic moulding machine by BFL-Karachi/Pakistan.
Bottle risering case histories

Green sand mould; \( M_S = 0.61 \) cm; feed metal required \( 4\% \times 2.85 \text{ kg} \times 3 = 342 \text{ g} \); riser 14 cm high, 2 cm top diameter. Base 10 cm diameter (increased because of 3 castings per riser); riser ratio 7:1; riser neck \( M = 0.55 \) cm. Riser neck 4.5 cm \( \times \) 1.5 cm; ingates (2) 3.5 cm \( \times \) 0.5 cm \( \times \) 12 cm long; runner 3 cm high \( \times \) 1.5 cm wide; downsprue 2.5 cm diameter \( \times \) 25 cm high; pouring temperature 1400°C; pouring time 9 sec; photo and data courtesy Bolan Engineering Foundry, Pakistan.

HUB PLATE: Ductile Iron grade 420/12; casting weight 2.85 kg; riser weight 2.85 kg; total poured weight 25.3 kg; yield 67.6%.
CASE HISTORY [ENGLISH SYSTEM (INCH: LB)]
- Heavy truck wheel hub casting. Weight 150 lb. (68 kg).
- Very high scrap due to shrinkage defect located at ‘A’. (Segment M₃)
- Green sand mould (weak).
- Significant modulus, $M_S = 0.77$ in.
- PCR method applies.

GATE / RISER SYSTEM
Part No: 770                   Company: ABC
Estimated Casting Weight: 150 lb

1. Layout:

2. Modulus = $\frac{V}{CSA}$

3. $M_N$ see Card #3

4. Riser modulus ($M_R$)
   $M_R = M_1$
   $M_R = 0.50$ in

5. Blind Riser Type
   Type 2
   $D_1 = 4.91 \times M_R (2.46) = 3.0$ in

NOTE: Max. $M_T = M_1 = 0.5$ in
Assumes good metallurgical quality of the liquid iron.

* Use a 3.0 in diameter riser to obtain adequate feed volume.
6. Riser Contact modulus \( (M_n) = .40 \) in  
See Card #4.

6b. Contact Shape  
<table>
<thead>
<tr>
<th>Shape</th>
<th>Side Length ( (M_n) )</th>
<th>Long Side ( (M_n) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square</td>
<td>4</td>
<td>1.6 in</td>
</tr>
<tr>
<td>Round</td>
<td>4</td>
<td>1.6 in</td>
</tr>
<tr>
<td>Rectangular</td>
<td>3</td>
<td>1.2 in</td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>2.4 in</td>
</tr>
</tbody>
</table>

7. Check Feed Volume  
Estimated Casting weight (each) = 150 lb  
Estimated Casting volume =  
\[ 150 \div 0.25 = 600 \text{ in}^3 \]  
Required feed volume =  
\[ 3\% \text{ of } 600 = 18 \text{ in}^3 \]  
Available feed volume “X” dimension = 4-1/2 in  
Available feed volume = 25 in³  
Number of risers required/casting = 1

8. Total choke cross sectional area (section 1.8) per casting.  
\[ A_c = 0.65 \text{ in}^2 \]  
(from chart)  
Number of gates. \( n_1 = 1 \) (per casting)  
Gate dimensions (4/1):  
\[ n (4a^2) = A_c \quad 4a^2 = 0.65 \quad a = 0.4 \text{ in} \]  
\[ 4a = 1.6 \text{ in} \]

9. Runner Bar:  
Cross sectional area, \( A_R = 2 \) to \( 4 \) \( (A_c) \)  
\[ = 3 \times (2) \times (0.65) = 3.9 \text{ in}^2 \] (2 chokes)  
Height = 2 x width, \( 2a^2 = A_R = 2 \) to \( 4 \) \( (A_c) \) (2)  
\[ a = \sqrt{3} \times (0.65) \]  
\[ a = 1.4 \text{ in} \]  
\[ 2a = 2.8 \text{ in} \]

10. \( A_S \geq A_c \sqrt{\frac{H}{h}} \) or \( A_c \leq A_S \sqrt{\frac{h}{H}} \)  
\[ A_S \geq 2 (0.65) \sqrt{\frac{10}{3}} \]  
\[ D^2_S = 4 \times (2) \times (0.65) \sqrt{\frac{10}{3}} \]  
Sprue diam. = 1.74 in  
or, total choke \( \leq 0.43 \text{ in}^2 \)

11. Pattern Yield:  
Volume of castings = 2 \times 600 = 1200 in³  
risers & contacts = 100  
sprue & basin = 62  
runner = 50  
gates = 1  
sprue well = 10  
Total volume poured = 1423 in³  
Pattern Yield =  
\[ \frac{\text{Casting Volume}}{\text{Total volume poured}} = \frac{1200}{1423} = 84\% \]
2.16 Metallurgical Quality Control and the importance of the nucleation condition

One of the most important factors involved in the risering of a casting is to understand and exercise some control over the way in which the solidification process takes place.

The schematic representation of the volume changes which accompany the cooling and solidification of ductile iron are shown above. As can be seen from the plots A, B, and C the volume changes are not constant, even for ductile irons of identical chemical composition, there can be differences in the degree of nucleation which will affect the volume change pattern. It is the “metallurgical quality” of the iron which is important and is directly related to the self-feeding characteristics (small volume changes) of the ductile iron.

2.17 Methods to measure the Metallurgical Quality

- Base Iron:
  chemistry and wedge test (check undercooling)

- After treatment and inoculation:
  chemistry (including Mg content), cooling curve analysis, and nodule count/modulus. (See page 24).

There is no universally accepted measure of metallurgical quality at the present time. Nevertheless we do have knowledge about the important features of raw materials selection, melting practice, magnesium treatment and inoculation – all of which influence metallurgical quality. From a practical viewpoint also it is important to maintain all conditions as constant as possible in order to ensure consistent volume change behaviour with consistent and predictable feed metal requirements.
2.18 Other Risering Aids

The reasons for using exothermic or insulating risers is that you can sometimes use smaller risers where the application dictates that the riser be cold (not gated into – such as a top riser and isolated risers). Normal risers use only a small portion (around 14%) of their volume for feed metal. Exothermic and insulating risers can give up to 80% and more as feed metal to the casting. These risers are also designed in relation to the significant modulus of the casting to be fed. In this case you can normally use relatively small risers to feed the castings even in heavy castings. The normal exothermic and insulating risers have, by their nature; an increased effective modulus of about 1.4 to 1.5 times in relation to sand molded riser. Another type of special riser system is called a “Mini-Riser” which is a small exothermic riser. This type will have an increased modulus of approximately 2.3 times.

To calculate the size of the risers, normally you should measure or calculate the significant modulus and casting weight. The actual feed metal required is about 3 – 5% of metal by weight. This is depending on the mould-hardness, metallurgical quality of the iron and pouring temperature. One should also consult the manufacturer’s recommendations on the use of these special types of risers. Maximum utilization of this “mini-riser” should be no more than 70% of its volume.

Example:
If we have a casting with a significant modulus of 2.5 cm and a weight of 20 kg you get the following riser: Weight of the riser = 3% minimum × 20 kg = 0.60 kg or 600 gr. ÷ 70% = 857 gr. of feed metal would be supplied. The riser modulus should be 1.1 × 2.5 cm = 2.75 cm.

The neck is also very important when using these risers. A breaker core is necessary between the casting and the riser. The diameter of the hole in the breaker core should be maximum 1/3 of the diameter of the riser. This has the advantage to avoid shrinkage holes in the riser neck and also it reduces finishing costs.

One further advantage of the “Mini-Riser” is that the pressure, which is created during the growth and expansion of the graphite, is not going on the mould, it is relieved by the riser because there is still liquid metal and a void in the riser. This type of riser was invented in a foundry where they produce hydraulic castings. This foundry has had great problems with penetration and cracking of the cores. After using the “Mini-Risers” the problem nearly disappeared, because now the feeding system was a pressure control system. During solidification the riser was feeding the castings with liquid iron and during the formation of graphite iron was forced back into the open riser and the pressure was released.

All exothermic risers contain aluminum and other elements to provide the reaction. These elements can often cause graphite degeneration. To avoid this problem you have to increase the height or length of the riser neck. There are also other elements that can cause casting defects if they get into the sand system especially in the unburned condition. Defects such as “Fish eyes” can be produced.
2.19 The use of chills

Since there are more methods of non-destructive testing performed on castings, foundries are forced to find economical ways to make completely sound castings. Ductile Iron has an expansion phase during solidification. If you have a slow solidification and a strong mould you can make sound castings riserless and most often with some chills. However the majority of castings are smaller and made in relatively soft green sand moulds. During the expansion of graphite the mould walls will yield and so it is not possible to use the expansion of the iron for the feeding of the castings. Ductile Iron is also a eutectic alloy. All eutectic alloys are liquid very long during solidification. They don’t form a skin during solidification. When using chills we quickly form a solid skin in the area where we have placed the chill. We also increase the density in the matrix producing fine structure in this area. This can help improve wear resistance and pressure tightness.

Most foundries are using chills made from Grey iron. The thickness of the chill should be at least the same size as the thickness of the section to be chilled. Adding chills to one side of a section can reduce the modulus by up to 50%. Grey iron chills can be used until they get cracks. Using chills with cracks may produce blow-holes in the area were you placed the chills. To avoid this problem foundries are using more SiC-bricks or graphite blocks as chills. They do not have as strong a chilling tendency as Grey iron chills, but they have no tendency to absorb moisture. Applying chills can reduce the number of risers and normally also the scrap rate. These things can increase yield and reduce finishing costs.
More bottle riser examples

Cross section through links and riser.

Cross section through links and riser.

Link castings connected by a bottle riser.

LINK CASTING: GGG80; casting weight 5 kg; green sand mould; $M_S = 1.5$ cm; modulus riser neck = 1.05 cm; riser diameter at parting $4 \times 1.5$ cm $+ 3$ cm = 9 cm; riser height 15 cm (5:1 ratio); feedmetal 741 g (needed $5$ kg $\times 4\% \times 2 = 400$ g); riser neck dimensions 2.5 cm $\times 6.4$ cm.
HUB CASTING: GGG40; one riser for 4 castings; $M_s = 1.0$ cm; casting weight each = 2.5 kg; green sand mould; $M_{neck} = 0.7$ cm; neck dimensions 1.8 cm x 6.0 cm; riser modulus 0.8 cm; riser dimensions (5:1 ratio) 3.0 cm top diameter; 15.0 cm high, diameter at parting 14 cm; feedmetal required 400 g; feedmetal supplied 741 g.
Use of bottle risers.
1. Chvorinov, N.
   Giesserei vol. 27 1940 page 177

2. Wlodawer, R.
   Directional Solidification of Steel Castings
   – Pergamon Press 1966

3. Karsay, S.I.
   Ductile Iron vol. 1 – Production published by
   QIT – Fer et Titane Inc. 1976

4. Karsay, S.I.
   Ductile Iron vol. 3 – Gating and Risering published
   by QIT – Fer et Titane Inc. 1981

5. Corlett, G.A. & Anderson, J.V.
   Experience with an Applied Risering Technique for
   the Production of Ductile Iron Castings
   AFS Transactions 90, 1983, 173-182

6. Gerhardt Jr., P.C.
   Computer applications in Gating & Risering System
   Design for Ductile Iron Castings
   AFS Transactions 1983, 73, 475-486

7. Karsay, S.I.
   International Foundry Congress, Budapest 1978
   paper 28

8. Karsay, S.I.
   “The practical foundryman’s guide to feeding and
   running Grey, CG and SG iron castings”
   Published by Ferrous Casting Centre
   Available form AFS Headquarters
   Des Plaines, U.S.A.

   Pouring rate, pouring time and choke design for S.G.
   Iron Castings”.
   British Foundryman, December 1985

10. Rödter, H.
    “An alternative method of pressure control risering
    for Ductile Iron castings.
    QIT – Fer et Titane Inc., June 1984

Comments to and criticism of this work are welcome.
Please write to:
Rio Tinto Iron & Titanium Inc.
Technical Services
770 Sherbrooke St. West
Suite 1800
Montreal, Quebec
H3A 1G1
CANADA

September 2000
PRINTED ON RECYCLED AND RECYCLABLE PAPER

Copyright Rio Tinto Iron & Titanium inc.
PRINTED IN CANADA BY TRANSCONTINENTAL, MÉTROLITHO DIVISION
Total Poured Weight (Incl. Risers) Per Choke. lbs.

Pouring Time Sec.
PRESSURE CONTROL RISERING METHOD

Significant Modulus ($M_S$) in

Riser Neck Modulus ($M_N$) in

Riser Modulus ($M_R$) in  ($M_R = M_N \times 1.2$)

Good Quality

Poor Quality

I
II
III

Card #3 English
USE OF CARD
Curved lines represent riser neck modulus ($M_N$). To find neck dimensions, follow diagonal line to $M_N$ (curved line). Where these lines meet read dimensions on a and b scales for neck size.
USE OF CARD
Curved lines represent riser neck modulus ($M_N$). To find neck dimensions, follow diagonal line to $M_N$ (curved line). Where these lines meet read dimensions on a and b scales for neck size.
Riser Diameter at Parting

Effective Feed Metal Volume

Topmost point of riser

Effective feed metal (shaded volume)

Topmost point of casting

"X" (cm or in.)

Effective Feed Metal Volume (cm³ or in.³)

Riser Diameter at Parting (cm or in.)