Foundries have to ensure the ductile iron castings produced meet the customer requirements. Some customers demand that the properties from the casting meet the specifications and others may settle for properties from separately cast test bars such as keel blocks or Y blocks. In some cases the casting sections may be such that we may not be able to get a standard test bar. Then non-standard test bars may have to be used from casting sections.

**Test bars from casting**

There should be an agreement between the supplier and the customer as to where the test bar will come from the casting. This is important as the properties can vary from place to place due to different cooling rates (nodule count, matrix differences and casting defects). This effect on cooling rate is addressed in a number of ductile iron specifications by reducing tensile requirements for thicker sections: SAE J434 (revised February 2004), EN 1563 (revised 2002), and JIS G 5502 (2001). It is very important to make sure the test bar location will not contain any shrinkage or inclusions, which will detract from the potential properties. Some customers recognize that the center sections of the castings may have microporosity and this porosity does not affect the function of the part. They specify the test bar to come from half section of the casting wall to avoid the porosity. Another factor to consider is the size of the test bar that can be obtained from the casting. Sub-size test bars are much more sensitive to flaws in the casting (microporosity, inclusions) or in test bar machining and testing. The largest size test bar should be used whenever possible to get the best measure of the casting’s potential mechanical properties.

ASTM minimum property standards were derived from separately cast test bars. These test molds were designed to be shrink free and when poured carefully will result in the maximum potential of the material property. Depending on the gating and risering system and pouring practice (including late inoculation), properties from castings may differ from separately cast test bars.

**Keel blocks**

This is generally a better method for getting test bars as the entire leg is risered so that shrinkage is not a problem in the test bar. Keel blocks have the added benefit that they allow certification of material properties without cutting and scrapping a casting. However, there may still be differences between the test bar and the castings due to section thickness variation and late inoculation; as a result the keel block results may not be fully representative of the actual casting’s properties. A variety of keel block test bar arrangements are shown in Figure 1.

Most castings produced in the Disamatic machines and some in the cope and drag machines receive late inoculation in the form of stream inoculation. The late inoculation is very potent in eliminating inverse and chill carbides and increasing nodule count. High nodule count usually results in better properties as long as the bar contains no shrinkage porosity or inclusions. To duplicate the inoculation in the mold or during pouring, keel blocks can be poured with late inoculation. To duplicate the cooling rate of the casting in the mold, keel blocks could be covered or shaken out at a particular time, to result in a similar microstructure to the casting. A timer could be used to shakeout at a particular time after pouring to minimize variations.

It may be general practice to pour test bars (keel blocks) every day to represent the different grades of iron poured during that day. This information is used to certify that castings meet customer specifications. It is also a common practice to test one leg of the keel block and if that test bar fails for some reason (slag, shrink etc.) then the other leg of the keel block will be tested. Sometimes when both bars fail, a casting section will be used to verify and certify the properties of that batch of castings.

**‘Y’ blocks**

There are three different sizes of ‘Y’ blocks depending on the size of the castings poured. The same factors that affect the keel blocks also affect the ‘Y’ block test bars. Apart from these factors, there are some other things to consider with ‘Y’ blocks. There are two test bar locations from ‘Y’ block test molds, one above the other. There is a distinct difference in properties between the bottom test bar and the top test bar. Differences are due to the following factors:
1. Nodule count: Cooling rate is slower at the upper bar location, thus reducing nodule count. Lower nodule count will lead to increased segregation and might result in porosity in the grain boundaries.

2. Inclusions: Lighter inclusions will tend to float. With slightly longer time for solidification of the upper bar, there could be more inclusions there than in the bottom one.

3. Shrinkage: Even though the test bars are risered, there could be more micro shrinkage in the upper bar.

4. Matrix: Due to lower nodule count, the matrix in the upper bar may contain higher amounts of pearlite.

5. Graphite percent: Due to longer time for solidification, the graphite may have a tendency to float to the upper bar and will result in increased graphite.

Other process variables that may exacerbate the differences:

1. Temperature
2. Magnesium residual
3. Rare earth content
4. Carbon equivalent

5. Turbulence in filling mold

The above factors can be minimized by careful pouring and late inoculation of the iron. Test bars should not be poured at very high temperatures. Higher temperature will increase the differences in properties between bottom and the top.

Use of quality index

To verify if the properties of the casting or the test bars meet or exceed the ASTM minimum properties, the test results can be plotted in a graph (yield versus elongation and tensile strength versus elongation as shown in the figures 2 and 3). If the matrix of the casting and the test bars are different from one another, properties can still be compared using this quality index. The properties of similar quality will fall on a curve that is roughly parallel to the ASTM minimum property curve. If one of the property value approaches the minimum value curve or drops below the curve then the quality is deemed to be inferior to the other one above the curve. A similar approach can be used referring to SAE, EN, or JIS specifications.

1” modified keel block mold arrangement. Mold inoculation in the pouring basin could be used to duplicate in-mold inoculation. Test bars should be checked for porosity.

1” Keel block

‘Y’ Blocks – 1/2”, 1” and 3” legs based on casting thickness

Figure 1. Test bar arrangements (refer to ASTM A536 for size recommendations for ‘Y’ Blocks)
Figures 2 (above) and 3 (below). Test points below the ASTM minimum property curves, as shown by the red curve, indicate substandard quality ductile iron bars. Main reasons for these are:
a) carbides, b) shrinkage, c) inclusions and d) poor nodularity.
Heat treatment will move the points parallel to the curve by changing the matrix as shown by the green curve. Except in the case of carbides heat treatment will not move the test points from below the curve to above the curve.

For further information on quality index concept, refer to ‘Quality and specifications of Ductile Iron’ by D. L. Crews, AFS Transactions 1974, pages 223-228 with discussions by C.R Loper and R.M Kotschi.