Foundry, as a potential casting supplier, is evaluated fairly by its customers using the following criteria: quality, delivery, customer service / support and any other relevant factors, while safeguarding confidential and proprietary information of both the casting supplier and the customer. Supplier’s responsibility for quality of its castings and/or services implies that foundry must ensure that its castings conform to all the customer’s requirements. Foundry must accept responsibility for any costs the customer may incur because of delivery of non-conforming castings. Shipment of non-conforming casting will jeopardize a foundry’s quality rating. Customer expects the foundry to use the following “casting supplier development process” before long-term partnerships are formed.

Supplier development is an evolving process through which customer ensures that:

- Customer’s standards for castings are clearly defined.
- Foundry’s quality system meets the customer’s requirements.
- Foundry’s processes are in control, capable, and product shipped to customer is defect free.
- Foundry works with customer to ensure that cast components are designed for manufacturability and cost effectiveness.
- Foundry works with customer’s QA to ensure that adequate quality planning activities occur.
- Customer’s sourcing decisions are based on the foundry’s commitment to work with customer to achieve zero defects and to provide continuous casting and cost improvements.

This supplier development process identifies suppliers that are committed to total quality, on-time delivery, competitive pricing, and technological expertise. This process reduces quality costs, with an emphasis on defect prevention techniques to reduce appraisal and failure costs. This includes unreported quality costs, i.e., requests for deviations, excess transportation, etc.

Supplier development process includes the following elements:

- * Customer conducts preliminary evaluation of the foundry.
- Foundry may be required to conduct a self-survey of quality system.
- Customer and supplier QA survey foundry’s quality system.
- Specs and control characteristics for the casting are identified.
- Foundry defines process flow and develops process FMEA when requested.
- Foundry develops control plan.
- * Foundry’s QA reviews control plan for technical soundness and approves final control plan.
- * Foundry performs process potential study, when applicable, and submits “initial sample inspection report” or ISIR with samples for final evaluation and approval by customer.
- * Customer dispositions the ISIR.
- * Foundry demonstrates process capability for control characteristics.
- * Foundry ships castings with zero defects or provides advance notice of potential problems to facilitate cooperative resolution.
- * Customer and Foundry QA evaluate consecutive shipments to verify effectiveness of controls.
- Customer will audit all certified parts on an annual basis.
- Foundry, Customer, Engineering, and Foundry QA identify opportunities for ongoing improvements in quality, delivery, price and technology.

* For each step highlighted, three pass / fail conditions exist as follows:

**Pass:** Progress to the next step.
**Conditional Pass:** Corrective action must be agreed upon before proceeding.
**Fail:** If corrective action is not taken, casting / foundry development process stops.

Casting production involves a number of activities. These include:
- procuring raw materials,
- manufacture of production tooling, e.g. patterns, core-boxes; fixtures and templates;
- sand preparation for green sand or chemically-bonded sand molding;
- core sand preparation; core-making, core-setting into molds;
- metal preparation, metal treatment e.g. desulfurization and carburization, magnesium treatment (for the production of SG Iron);
- inoculation;
- mold pouring, casting cooling and shake-out or knock-out;
- (despruing) or gates and feeder removal, shot-blasting, fettling;
- inspection (mechanical and metallurgical);
- fixturing – if required;
- mechanical and other physical testing, such as hardness, sonic and ultrasonic testing, radiography, etc., painting and despatch.
- Design of risering and gating system is part of the production tooling manufacturing.

Looked in totality the above list of activities indicates that production of castings is a complex and difficult job especially when apart from most of the known variables that can affect the casting quality, there are a number other variables, not specifically known or properly defined that can interfere with the casting process.

However, each of the process involved in the production of casting can be looked up on as a system that can be defined by specifying the parameters of each of its inputs, defining the time-sequence and details of the activities taking place inside the process or the ‘black box’ and identifying the measurable values of the parameters or the quality requirements of the product emerging from this process ‘black box’.
This approach is very similar to the one used in purchase of raw materials. The quality of the raw materials is defined in the material specifications where the material tests and acceptance criteria are defined. Once the incoming material is inspected against these quality norms and found to be compliant, it is taken into the Store.

This is the underlying principle of the system-approach to casting production. Each of the production process-step, high-lighted by a bullet above, produces an output. This output or the process product is checked for its compliance to the required quality that is defined in terms of specific measurable values of the product’s parameters. Once this product is accepted, it is taken into the Store, i.e. is allowed to go as an input to the next process-step. It, along with other inputs, undergoes some other operation in this next process ‘black box’ as per its operating instructions, and emerges as a new output or product. This goes on from the receipt of raw materials in the Store to the despatch of castings to the end-user or the customer.

Process approach requires that the quality of each of the inputs to a given process be defined completely in terms of a measurable entity. It also requires that each of the activity inside the ‘black box’ of the process be properly defined, in a measurable manner, so that the process can be unambiguously monitored. This is necessary so that the process produces the exact output or a product that meets the requirements of the input to the next process. When the process flow is thus mapped in detail, it helps the foundry man to be pro-active i.e. anticipate what is likely to go wrong in the process ‘black box’. And if something does go wrong, how does it affect the output product quality. This forces him to document his reaction to the product quality. Whether to scrap the product or repair, recheck and use it if found suitable, etc.

All these requirements must be suitably documented e.g. prepare detail process flow diagrams indicating the operation or activity, transportation or move, inspection or testing –quality or quantity; delay and storage. Operation description: describes the activity performed at each operation. The information should provide sufficient detail to understand the process, equipment, and tools used and changes being made to the product. The control points and sub-contractors should be indicated at the appropriate points in the flow diagram. Affected characteristics describe the area or physical aspects of the features that are being generated by that operation. One can include comments that list pertinent information such as potential causes of variation.

From this process flow diagram it becomes easy to prepare a pFMEA or the process failure mode and effect analysis sheet. This pFMEA should be looked upon as a ‘live’ document which gets referred to every time something goes wrong in the process or a new unforeseen problem is encountered. Every time a new problem is resolved, it should get automatically included into the pFMEA so as to keep this important document is always kept up-dated.

The next activity is to prepare a Control Plan for the process using the process flow chart and the pFMEA. The control plan defines the tests, their frequency and the reaction should something go wrong. Like the previous documents, this control plan is also a ‘live’
document that must be up-dated from the moment the initial sample castings are made, to prototype production, to series production. The results of the various tests carried out as per the control plan need to be documented on control charts where the trend of the results are used to monitor the process and make small course correction in time so that the process always continues to produce the required product quality.

Specific Requirements for a SG Iron Foundry

Majority of SG Iron is produced in as-cast condition without the need for heat-treatment, in the following three groupings:

1. Ferritic SG Iron: (grades 350/22; 400/18; 420/15; 450/10): Graphite spheroids in a matrix of ferrite, which is almost pure iron. High impact resistance, good machinability and fairly good corrosion resistance and moderate strength.
2. Ferritic – Pearlitic SG Iron: (grade 500/7): Graphite spheroids in a mixed matrix of ferrite and pearlite. Good machinability, easy to produce. Mechanical properties in-between those of the ferritic and pearlitic grades.

Cast irons, both gray and SG are ‘expanding’ metals. That is, during their solidification or transformation from liquid to solid, free graphite phase emerges from the liquid metal. As the density of this phase lower than that of the liquid metal from which it comes out, it needs more volume for its existence. This need of this graphite for more volume, to a large extent compensates for the decrease in the volume fraction that the liquid metal undergoes from the moment it is poured into the mold, say at 1400°C till the beginning of solidification, and say at 1200°C. This expanding metal needs different approach to feeder design as compared to the approach used for designing the feeders for steel castings. Actually, there is considerable pressure exerted on the walls of the mold when the graphite begins to precipitate from liquid during solidification. As these green sand molds are inherently weak, their walls cannot withstand the solidification pressure. As a consequence of this, there is mold wall movement due to which there is additional need for the feed metal by the casting. Hence, feeders are required for machine-molded green sand castings. However, if the mold is rigid and can withstand this solidification pressure, it is possible to produce large gray and SG iron castings with little or no risering. Certain constraints need to be used and observed while adopting riserless casting production methods. These are addressed while considering the gating and feeder design process for these castings.

Major foundry variables that affect the metallurgical quality of these metals are:
- Melting equipment.
- Metallic charge.
- Melt temperature in the furnace.
- Melt holding time in the furnace.
e. Melt composition / chemistry.
f. Metal treatment – desulfurization, magnesium treatment and inoculation
g. Effect of specific elements in the melt composition.

Practical tips for induction melting:
a. All melting charge materials MUST be clean. Do not use oily or plated scrap. Scrap should be free from rust. Foundry returns should be used after tumbling i.e. free from adhering sand.
b. Steel scrap punchings should be hydraulically baled so that maximum power can be drawn from the beginning of the melt cycle.
c. Carburizer should be added with the steel scrap in stages for its maximum recovery.
d. Foundry returns or sprue should be charged towards the end.
e. Aim at a slightly higher value of the carbon analysis than the target. Carbon can be reduced by the addition of steel scrap quite effectively. Trying to increase the carbon content through the use of carburizers towards the end of the melting cycle is difficult and often gives erratic recovery.
f. Do not superheat the melt more than the desired tapping temperature. Metallurgical quality of the melt deteriorates on its superheating e.g. loss of inherent graphite nuclei. Remember melt cold and pour hot.
g. All input materials and the liquid metal used for magnesium treatment MUST be weighed.
h. Slag should be completely removed before tapping the metal for magnesium treatment. After treatment, at each transfer point, remove the slag and inoculate.

General guideline to S. G. Iron composition is to select the carbon equivalent with respect to the nominal wall thickness of the casting. Specific carbon and silicon values will be governed by the fact whether impact strength is required or not and how carbon flotation is to be avoided. Generally, these limits are fixed by the two boundary conditions:

Total Carbon + $\frac{1}{7}$ Silicon $\geq 3.9\%$ to avoid shrinkage defects; and,

Total Carbon + $\frac{1}{3}$ Silicon $\leq 4.55\%$ to avoid carbon flotation.

Recommended chemistries, manganese contents for various grades and casting wall thickness are readily available in published literature.

After the magnesium treatment it is necessary to inoculate the metal for chill removal, increase the graphite nodularity and count, improve the mechanical properties, produce consistent microstructure and mechanical properties and, to have uniform properties in varying section thickness of the casting. The general principle – ‘treat first and inoculate afterwards’ is traditional and still valid. ‘Post inoculation’ (meaning inoculating after the magnesium treatment) is more effective simply because it is done later and at a temperature, that has been lowered by the cooling effect of the treatment. The effectiveness of residual magnesium content and inoculation fade with time.
Requirements of feeding and gating system elements. Objective is to produce castings without shrinkage defects, economically with maximized casting yield. Green sand molds are not rigid enough to withstand the expansion pressure of the solidifying metal. Hence, feeders are required. Feeder function is quite sensitive to pouring temperature and pouring time.

It is essential that the feeders used are blind feeders (not open feeders) because the use of open feeders causes the volume increase associated with the ‘expanding SG iron metal’ lost to the casting as pressure in the feeder is released by way of exudation out of the feeder. When closed or blind feeders are used this volume expansion is available to the casting and the casting is internally sound.

Molds must be filled with as little turbulence in the metal as possible and mold filling must be fast. The first metal that enters the mold must be kept in the runner extension and not permitted to get into the casting cavity. Fast mold filling needs efficient mold venting so that there is no back pressure of mold gases to oppose the metal flow.

It is strongly suggested that the gating system should deliver the metal only at bottom of the mold cavity using a non-pressurized gating system. As this metal rises to fill the mold cavity the liquid metal front in non-turbulent and pushes the mold gases ahead of this front and out through the mold vents. Core gases must be vented through the core vents of course. Always gate into thin sections.

Important process controls in S.G. Iron production:
  - Initial sulfur content (before magnesium treatment)
  - Weighing all additions to the furnace and the metal including the weighment of the metal taken for treatment.
  - Treatment procedure
  - Inoculation practice / technique.
  - Metal distribution time.
  - Examine melting scrap for the presence of deleterious elements. If there is doubt of some of these elements lurking in these charge, consider using cerium-bearing treatment alloy
  - Residual magnesium content – to be monitored as per the casting wall thickness.
  - Carbon analysis to be carried out periodically by the combustion method as the spectro results may not be precise if the coin samples are taken improperly.
  - Where high-cerium bearing treatment alloys are used, include the cerium content into the residual magnesium analysis required for getting required graphite nodularity. If this is not done and normal levels of magnesium residuals are targeted, castings will have carbides and lead to machining difficulty.
  - Use only gray iron for chills. Heavy section S. G. Iron castings need chills to avoid degeneration of graphite nodule shape. Generally, when chills are used on both sides of the casting wall, the chill thickness should be about 33% of the wall thickness. When used on one side of the casting wall, the chill thickness must not be more than 45%.
Control return sand temperature. Sand temperature should be close to 100°F or about 38°C.