Ductile Iron News

Ductile Iron Society

To Promote the production and application of ductile iron castings — *Issue 1, 2002*

The Ductile Iron Society Exhibits with AFS at the Detroit SAE Show

FEATURES

DEPARTMENTS

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Formation of Inductotherm Group

Press Release - **Formation of Inductotherm Group**

Henry M. Rowan, Chairman & Founder of Inductotherm Industries, recently announced at its world headquarters in Rancocas, New Jersey, the formation of the Inductotherm Group. During Inductotherm Industries' growth, a number of diverse companies with a wide variety of equipment and skills for the metallurgical industry joined our organization. The benefit to our customers will be enhanced by coordinating the broad knowledge invested in these individual companies. The Inductotherm Group includes such world leading names in the industry as Inductotherm, Inductoheat, Lepel, Thermatool, Consarc, Bricmont, EMSCO, HI T.E.Q., Radyne, Welduction, and Newelco.

The benefits to our customers are many. Customers now have access to a broader, more diversified portfolio of products, technologies, and services to best meet their needs. Customers are also able to enjoy the benefits of size and scope of the Group, and a commitment to industry leadership. Additionally, the Groups= products are enhanced by focused research & development, engineering, support and sales.

John H. Mortimer, P.E. was named President/CEO of this group. Mr. Mortimer joined Inductotherm in 1969. He was named President of Inductotherm Corp. in 1984 and Chairman/CEO in 1997.

The Inductotherm Group is divided into five main product groups, headed by group CEOs, reporting to Mr. Mortimer:

The Consarc Group, headed by William J. Marino, President/CEO, consists of Consarc Corp., Calcarb, Inc., and Consarc Engineering Ltd. This is a high tech group dedicated to the melting and remelting of specialty super alloys for the aviation and aerospace industry and reactive metals and alloys.

The Engineering & Services Group, headed by William M. Goodlin, President/CEO, consists of Inductotherm Automation, Inc., ABPlan GmbH Co. KG, Bricmont Inc., Shamrock Automation Inc. and EMSCO Inc. This group is dedicated to engineering including automation controls and robotics applications, as well as after market services.

The Furnace Group, headed by J.H. Mortimer, President/CEO, consists of Inductotherm Corp. and its worldwide affiliates whose principal products include induction melting furnaces and induction power supplies, charging and preheating systems, automatic pouring systems, and computer control systems for the metals and advanced materials industry. Inductotherm Corp. is headed by Paul B. Cervellero, President. This group also includes HI T.E.Q. Inc., a key supplier of a complete line of high quality processing systems for the aluminum industry.

The Heating Group, headed by Byron L. Taylor, President/CEO, consists of Inductoheat Inc. and its worldwide affiliates, Lepel Corp., Radyne Corp. and its affiliate companies, Strayfield-Fastran Ltd., IHS Inc., Inductoheat Banyard, Ltd., HWG Inductoheat GmbH, Newelco, Welduction, Alpha Inc., and ADM Electrodes Ltd. This group is dedicated to designing and manufacturing induction and dielectric heating equipment, heat treating and mass heating equipment, high temperature combustion engineering equipment.

The Welding Group, headed by Gary A. Doyon, President/CEO, consisting of Thermatool Corp., Thermatool Europe Ltd., and T & H Lemont. This group focuses on high frequency induction welding equipment, pipe and tube mill systems,

complete roll forming systems and tooling.

With all product groups under one leadership, the Inductotherm Group will continue to provide high quality equipment and excellent service to its worldwide customers in the metallurgical industry.

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Practical Methods for the Control of the Inclusion Content in Ductile Iron

by Arthur F. Spengler

Based on the findings from Ductile Iron Society Project No. 20, which is concerned with the subject of ductile iron machinability; it has been determined that as the inclusion content in ductile iron increases, machinability declines and tool wear is substantially reduced. In addition to reductions in machinability the presence of inclusions reduces the overall mechanical properties. While these conditions have been known to exist for many years, the Research Committee of the Ductile Iron Society held Project No. 18 in abeyance for approximately two years pending verification of the influence of the various types of inclusions on the machinability and mechanical properties of ductile iron. Currently, it is the considered opinion of the DIS Research Committee that the fact that all inclusions have a detrimental influence on the machinability and mechanical properties of ductile iron. In view of this fact, a different approach to the influence of inclusions on the machinability and mechanical properties will be studied.

Inclusion control in ductile iron castings is not necessarily a new or unique factor. In the past, there were many casting producers who did not consider it important to their customer. It was simply considered as an extra cost, which was not given any consideration unless the casting customer made it an issue, When this occurred, casting producers always have made an effort to renegotiate casting prices upward based on the increased costs to cover the additional expense.

It must be pointed out that all graphitic cast irons, which include ductile iron, are not homogenous metals in the same sense as non-ferrous metals, steel, and unannealed malleable iron (white-iron or hard iron). They are in fact mixtures containing graphite more or less evenly distributed in a metallic iron or steel-like matrix. 1n the case of ductile iron, the graphite is present in the spheroidal form. The basis for nodule or spheroid formation is the presence of large quantities of heterogeneous nuclei. These consist of micron size nonmetallic inclusions and other stable micron size inclusions in the form of inter-metallic compounds. As a result, graphitic cast iron contains relatively large quantities of what can be teamed inclusions. In fact, if these inclusions are not present in sufficient quantities, flake or spheroidal graphite will not form. These nuclei come from many different sources, which Include furnace charge materials, magnesium ferrosilicon treatment alloys, and inoculants. Under certain conditions, when an excess of these materials is present they will coagulate to form slag. Refractories, both from furnace linings and ladles, can be another source of nuclei and slag. In addition, there is always the magnesium vapor, which continually comes out of treated molten ductile iron to form magnesium oxide and magnesium silicate. All of these different compounds which are considered as sources of heterogeneous nuclei not only contribute nuclei to the ductile iron process, but also act as a source of inclusions in the metal as well as a source of slag in castings, if present in excess. In addition to products of melting and the treating reaction, as well as inoculation, there are inclusions in the form of inter-metallic compounds and carbides of chromium, molybdenum, vanadium, and carbides, formed by the presence of rare earth metals, which collect in the grain boundaries if the solidification rate extends over sufficient or critical length of time (the time required to pass through the interval between LIQUIDUS and SOLIDUS phases) which is reduced as the level of residual elements in ductile iron increases. It appears that the increased accumulation of these extraneous materials in the grain boundaries substantially reduces the mechanical properties of ductile iron. This is one of the least understood phenomena related to the production of heavy section ductile iron castings.

While inclusions and slag from treating material, inoculants, and other sources will always be present in ductile iron even under the most ideal processing conditions; it is possible to minimize this condition by taking certain precautions. These

practices can be introduced in any foundry producing ductile iron castings. The main objection is the apparent increase in casting cost, which inevitably occurs. As a result, such practices are never introduced except at the demand of the customer. This attitude has always prevailed, in spite of the fact that these practices can improve casting quality and simultaneously, actually reduce processing costs. It is a condition which exists primarily in those companies where the purchasing department's only consideration is price alone, and where management is not sufficiently sophisticated to understand the value of improved machinability and casting quality on the overall cost of the finished components.

There are a series of steps, which can be taken in any foundry to substantially reduce, and control, the levels of excess inclusions present in ductile iron castings. Basically, they involve the quality control of furnace charge materials, and an understanding of Stoke's Law, relative to dross and slag removal, from base iron melting furnaces and treatment ladles. Descriptions of the steps and procedures needed to minimize the presence of excess inclusions are as follows:

1. One of the initial sources of inclusions is the melting material. This includes excess rust (iron oxides) and dirt (silicon dioxide), which is always present. The main source of slag in the melt is the molding sand, which adheres to returns.
2. One more significant source of inclusions is alumina, and also silica slag from furnace refractory. The quality of refractory used in melting and pouring requires serious consideration.
3. One of the most overlooked slag and inclusions source, is the slag that is present in under-Cooled blast furnace pig irons. This includes charcoal-reduced pig iron, coke-reduced pig iron, and on occasion, submerged arc-furnace pig iron. Slag from the pig irons described here, contain substantial amounts of iron oxide, and are very fluid. As a result, they require the use of dry slag coagulant such as unexpended vermiculite. Even then it is not always possible to overcome the dilatory effects this type of slag.
4. Another source of slag in ductile iron base irons is the oxides and silicates contained in sponge iron pellets and pre-reduced iron pellets from various sources. The unreduced oxides contained in these materials usually ranges from 8.0% to 15%, which is a significant volume.

In order to remove or minimize the presence of these and other sources of slag and inclusions from the base iron, it is necessary to utilize the concept of the Brownian Movement to allow the sources of inclusions to float to the surface of the metal in the furnace. This can be calculated, based on time, temperature, and slag density. Once these oxides come to equilibrium, they will float out of liquid metal at the rate established by Stokes Law:

$$V = \frac{2gr\backslash 2\ (d1 - d2)}{9/n}$$

Where V is the rising velocity in cm per sec, if g, the acceleration due to gravity, is cm. Per sec\2, r is the radius of the particle in cm, d1 the density grams in per cubic cm. of the liquid, d2 the density grams per cubic cm of the suspended particle, and n, the viscosity of the liquid in dyne-sec. Per sq. cm. or poises. In liquid iron, or steel, the formula can be reduced to:

$$V=8.38 \times 10\ (6.94 - d)\ r\backslash 2$$

For example a particle of 30 microns in diameter will rise 5 ft. in 30 minutes, while a particle 300 microns in diameter particle will rise 5 ft. in 21 seconds, and a 1 mm particle will rise 2 ft. per sec.

In a typical coreless induction furnace base iron melting operation, the time for power-off allowed for slag flotation, is usually from four to ten minutes. In a situation where extremely rusty scrap and or large quantities of sponge iron are used in the furnace charge, longer times may be required. When all of the slag from melting has floated to the surface, the furnace should be tilted back, and the slag skimmed off. If slag coagulants are required, the quantity used should be kept to the absolute minimum required for effective slag removal, and no more.

In the case of desulfurized cupola melted base irons, regardless of the

desulfurization practice, slag removal required the following steps:

1. Refractories used in desulfurizing ladles, must be extremely resistant to the corrosive action of the desulfurizing media.

2. After desulfurization, using a porous plug or other mixing device, sufficient time must be allowed for the sulfide slag to float to the surface of the base iron in the desulfurizing ladle. This usually involves time intervals ranging from three to fifteen minutes, depending on the ladle size and metal temperature.

It is very important that the time interval involved be held to an effective level, which will minimize temperature loss and sulfur reversion, and at the same time provide optimum sulfur removal.

3. Slag removal and cleaning of the desulfurizing vessel is absolutely necessary, otherwise the channel in the holding furnace will become plugged in a very short time, and there also can be a serious sulfur reversion problem in the holding furnace.

Up to this point, the subject discussed has been the melting and preparation of the base iron. Based on our collective experience; it is very obvious that while the major part of the slag generated in base iron melting and preparation, will float to the surface of a still or non-active molten metal bath. Small particles of slag, which are 20 microns or less in diameter float up to the surface of liquid metal at a relatively slow rate, and in some cases, based primarily on size and density, remain in the liquid metal, and cannot be removed except by filtration. The use of clean, oxide free, charge materials, along with proper slag coagulation and removal techniques, minimize the accumulation of dross and slag in base irons used in ductile iron production.

The last and major source of dross and slag inclusions, are the treating material and treating practices, including inoculation practices. There are a substantial number of treating procedures using magnesium-ferrosilicon, nickel-magnesium, and magnesium metal. The cleanest, and most effective procedures are those, which require large quantities of treating alloys, and produce ductile iron castings with high casting scrap levels.

The on-going viability of any practice is determined by the acceptance or rejection, by the casting purchaser. This can be based on quality or cost. The last considerations, and possibly the most important, are the treating materials and inoculants used in the ductile iron process. These ferroalloys, magnesium metal, and inoculants, can, and do, have a profound influence on the cleanliness of the ductile iron castings produced. The following is a list of quality factors, which should be taken into consideration when treating materials, and inoculants are chosen:

1. All magnesium ferrosilicon alloys contain magnesium oxides, magnesium silicates, and various forms of dross, which are the result of magnesium metal cleanliness, and the method by which the magnesium metal is introduced into base 50% ferrosilicon. The most effective procedure is to plunge virgin magnesium ingots into the liquid 50% ferrosilicon under an inert gas cover in a covered ladle. When scrap magnesium is stirred into the ferrosilicon, the result is always large quantities of oxides and dross. In general, the oxides present in a 5% to 6% magnesium ferrosilicon should never exceed 0.5%. The effective magnesium level in the form of magnesium silicide must be in the range of 5% to 6%.

2. When magnesium ferrosilicon alloys are produced, it is very important to consider the method of solidification. For example, when magnesium ferrosilicon is poured in thick sections in open molds, a heavy layer of oxides and silicates occur on the surface exposed to the atmosphere. This oxide and silicate layer, if not removed, becomes a major inclusion source.

3. The overall structure and solidification pattern has a significant influence on the reactivity of magnesium ferrosilicon treating alloys regardless of the calcium level of the alloy. For example, the magnesium ferrosilicon alloys cast in an open mold having a thickness of 5 to 6 inches or 25 to 150 mm will solidify with large columnar grains of magnesium silicide and iron silicide, which are plainly visible. The presence of these large magnesium-silicide grains, cause increased levels of

violence and oxidation in the treating reaction, regardless of the quantity of calcium or barium present in any magnesium ferrosilicon-treating alloy. Chilled thin cast materials with thickness in the range of 0.75 - 1.25 in. results in magnesium ferrosilicon alloys with a relatively fine-grained mixture of iron silicide and magnesium silicide, which reacts at a relatively moderate rate.

4. Another important consideration is the violence of the treating reaction. Calcium and barium suppress the violence of the treating reaction, and their presence, in sufficient quantity, can increase magnesium recovery very dramatically up to as high as 75%. The optimum level calcium in a 5% magnesium ferrosilicon alloy is between 2% and 2.5%. The barium level for suppressing reactivity is between 5% and 6%. This is also the level at which maximum nucleation occurs.

5. In processes where pure magnesium metal is used to introduce magnesium into the base iron, every possible effort must be made to minimize the violence of the treating reaction and thus reduce the presence of oxides and silicate slag produced in the process. This can be done by creating back-pressure in the treating vessel by having a silicon content of approximately 2.0% or more in the base iron, and by adding calcium silicon and other high silicon material, such as silicon metal and/or 75% ferrosilicon along with the magnesium metal addition.

6. It is common knowledge that both crushed and sized treatment alloys and inoculants oxidize when exposed to the atmosphere starting at the time of crushing and sizing. Sea voyages are particularly detrimental in this respect because of the high levels of moisture and chlorides present in the atmosphere. These are factors that can cause reduced magnesium recovery, and at the same time significantly increase the presence of inclusions in ductile iron castings.

In the case of inoculants crushed to relatively small sizes for use in stream injection, can have losses in effectiveness up to 70% due to a few months exposure during storage. This is particularly true of crushed ferrosilicon fines, which are available at very attractive prices. This problem of erratic stream inoculation chill control can be minimized by the use of fresh crushed inoculant.

7. One source of very destructive massive inclusions is undissolved inoculant. This material has been known to seriously damage cutting tools and machining fixtures resulting in hundreds of thousands of dollars in scrapped castings. The use of exothermic inoculants may become a mandatory part of ductile iron production. This is necessary along with a pouring temperature exceeding 2450^{o}F depending of the section size. For example, 50% ferrosilicon is endothermic having a cooling effect on the iron. The exothermic range starts at approximately 62% silicon, which is exothermically neutral and ending with approximately 90% silicon, which is strongly exothermic. Ductile iron requires an exothermic inoculant with at least 75% silicon in the form of iron silicide and metallic silicon. Such inoculants will go into solution and generate their own heat of solution simultaneously. After giving this matter thoughtful consideration, in-stream ferrosilicon inoculants with silicon levels in the range of 85% will probably be the most effective, and have a highest practical exothermic level. Inoculants in the endothermic range below 60% silicon will not go into solution on hitting the stream. Such inoculant can only be used for ladle addition.

Conclusions and Recommendations

While there may be additional sources of inclusions in the ductile iron process other than those described here, these are the primary sources. When the level of inclusions present in ductile iron castings increases, the mechanical properties decline. Their presence can be reduced substantially by taking the corrective actions described in this report. In general, any operating ductile iron foundry can improve casting quality without the purchase of any costly capital equipment, however; there may be some increase in the cost of the melting and treating material used in the process. These will be compensated for by overall reductions in casting scrap. In addition, there will be fewer scrap castings returned by customers. This alone will promote customer confidence in the casting producer.

The production of ductile iron castings suitable for A.D.I. requires the use of every possible precaution that will minimize the presence of all types of inclusions. This can only be done by careful adherence to recommendations outlined here along with the application of low stress casting design criteria to all Austempered Ductile

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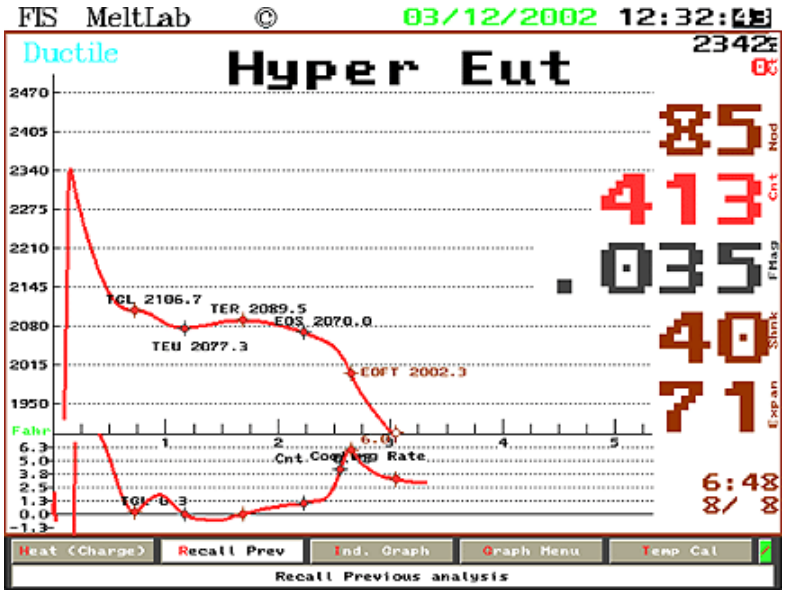
The Effect of Different In-Stream Inoculants on the Solidification of Ductile Iron

A Report to the Ductile Iron Society
March 12th 2002
By David Sparkman

Abstract: *A new breed of inoculants has come on to the market offering greater improvements in shrinkage prevention with the promotion of late graphite growth and high nodularity count by using an engineered inoculant containing many more ingredients than the older inoculants. These ingredients can include specific rare earths as well as graphite and sulfur. This is a first look at how two of the main inoculants work to change solidification characteristics.*

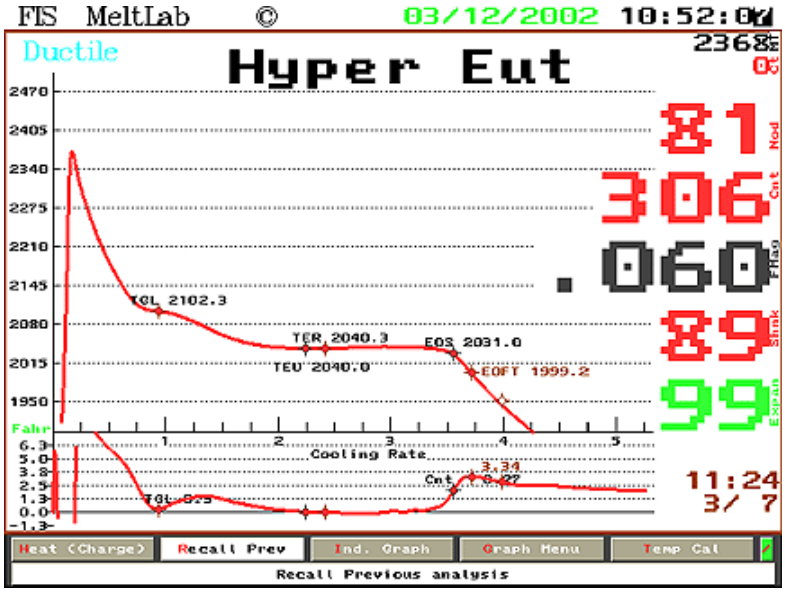
Recent changes in DI MeltLab program
With added experience in Ductile Iron final analysis, the MeltLab program has been revised to change the scaled Shrinkage numbers to reference numbers that range from 0 to 100 with 100 being the best, and zero being the worse. In addition, at the suggestion of Dr. Torbjorn Skaland, we have developed a method of measuring the energy production of the late graphite that is so very important to preventing shrinkage. We are calling it the expansion potential of the iron. This value seems to decline markedly with carbide formation, and appears to us to show the completeness of the carbon to graphite process. It may be interesting to look at this value with pearlitic irons.

As this was a quick experiment, no lab work was preformed to calibrate the nodule count with the MeltLab. The results may be slightly low. The nodularity results seem in line with the foundry experience of 90%, and the Lab's final Magnesium was running about 0.045% on an older spectrometer. The MeltLab reports effective magnesium which is the magnesium less the mag-sufides and mag-oxides. These final numbers seem in line, though the pouring furnace seems a bit high so the equations may need to be recalibrated for Fischer type of iron.



This is an example of new shrinkage and expansion values. This sample shows low expansion and moderate shrinkage potential, possibly due to hypereutectic arrest.

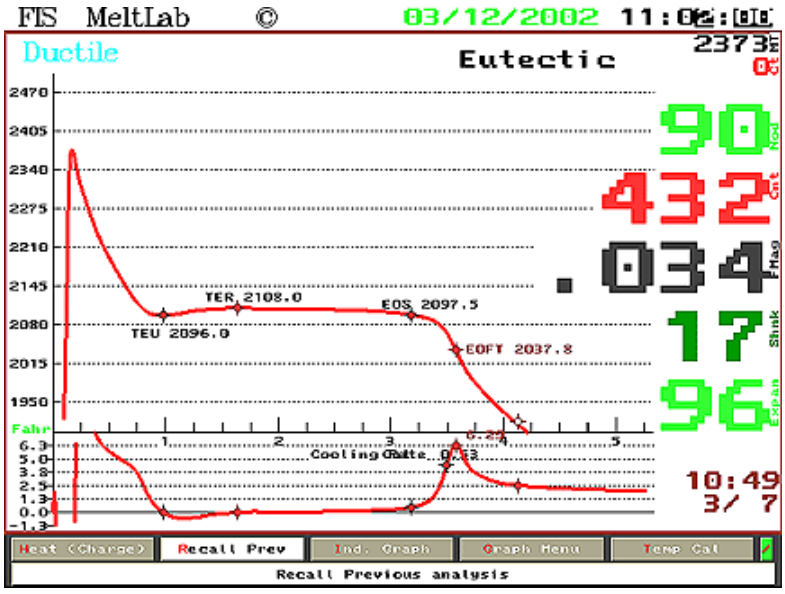
Pouring Furnace Iron
This iron is clearly a hyper-eutectic iron that shows the relative high magnesium content from a Fischer converter.



Further, the sample is highly shrinkage prone (89) but no carbides are showing up, and the graphite expansion is very good. The major problem with this iron is that it is Hyper Eutectic as shown by the two arrests. This drives out a lot of the necessary carbon in the graphitic liquidus and the iron looses about 10% of the ability to counteract shrink. Multiply a 10% loss in late graphite times a 10% volume of graphite, and the result is a 1% of volume shrinkage defect concentrated in the last iron to freeze.

First Inoculant trial

A measured amount of this inoculant is used to produce nodularity samples by placing the inoculant in the mold and filling it with iron. We used the same amount in a non-tellurium cup and produced the following results:



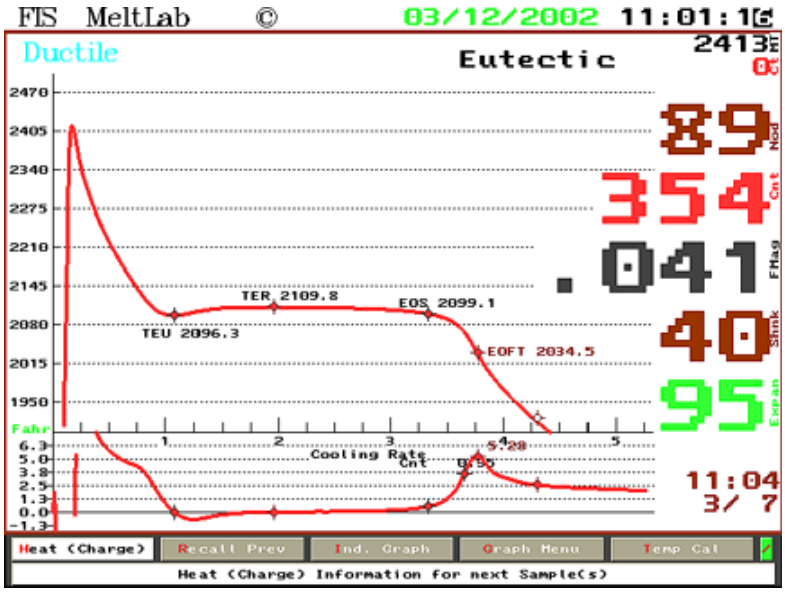
The inoculant sharply reduced the shrinkage potential and changed the solidification mode to eutectic. Where in the pouring furnace iron, the bulk of solidification occurred between 2040.0 and 2040.3, here the solidification is occurring between 2096.0 and 2108.0, a major change of over 60 degrees higher.

With the addition of sulfur in the inoculant, the magnesium is a little lower than the second inoculant trial. But the result is an excellent shrinkage value of 17, and a very good expansion value of 98 along with a significant increase in nodule count.

Second Inoculant Trial

This is a new product from a major manufacture. We are not sure of the exact chemical content, but it is reportedly lower in sulfur. Hence we have a slightly

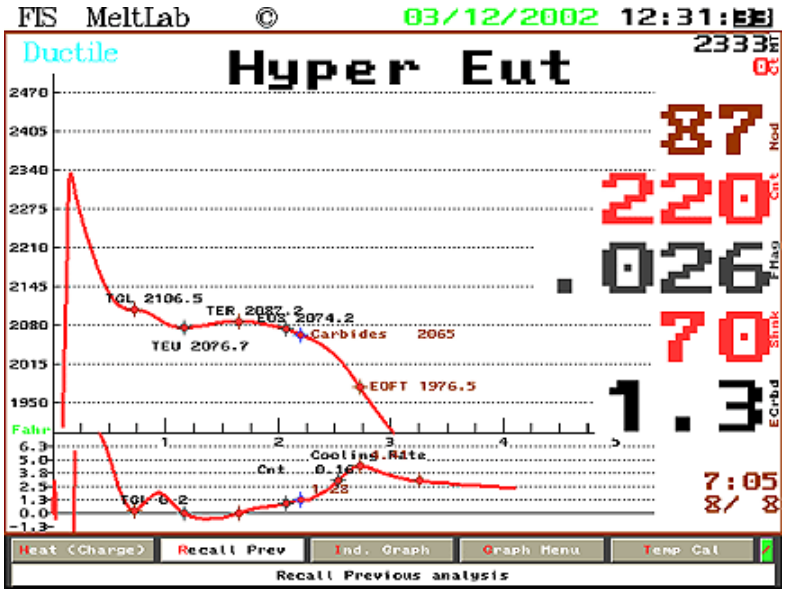
higher effective Magnesium content. The Lab was reporting an 0.045 total magnesium at this time. The same method of measuring was used on this cup as in the first inoculant trial, and the test was preformed 15 minutes later.



Here the bulk of solidification occurred between 2096.3 and 2109.8 degrees. This is extremely close to the previous trial of 2096.0 and 2108.0, with the difference in the higher number reflecting more effective magnesium.

The nodularity on the second sample is almost identical at 89 vs. 90. The nodule count is 50 points lower, the mag is higher due to lower sulfur in the inoculant. But the surprising result is that the shrinkage potential of this iron is significantly higher (40 vs. 17) even though the expansion value is almost the same (95 vs. 96).

Carbide example from MeltLab Archives



This is an example of an iron with very low graphite expansion that resulted in actual carbide formation. Due to the low magnesium, this could have been carbides in d or e-flake. Note how the rate of cooling rises at the end of the eutectic reaction. This iron was not from the same foundry, and was inoculated with only ferrro-silicon.

Conclusion

Thermal analysis does show the expected trends in effective magnesium, nodularity, and nodule count. While the new expansion number confirms the

absence of carbides, the shrinkage number seems to show the most difference between the inoculants. By keeping the value of the shrinkage number instead of just showing Good/Bad, it is possible to quantify one inoculant from another. The Good/Bad evaluation is conveyed by color-coding the values Green, Yellow (brown here for readability on paper) and Red.

And Thanks

FIS cannot afford the kind of research done by major universities or large corporations. We are dependent on the generosity and help of the foundries we work with. We thank all those who have helped in this, though they remain confidential.

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Something Has Been Changed

Art Spengler Lecture No. 1

There are always reasons why things go wrong. Often they are apparent; sometimes the causes are obscured by other things. This is particularly true when dealing with the causes of casting scrap. To find the cause, an investigative procedure must be followed, which is designed to meet the needs of the foundry.

The production of castings can be a relatively simple procedure, or extremely complicated, depending on the types of castings being produced and the metals from which they are poured. Here are a few simple steps which should always be followed to determine the source of casting defects and their cause.

a. Examine the evidence. Be absolutely sure that the castings are, in fact, defective, and not the product of overzealous quality control. Changed standards/increased inspection.

b. If the castings have been rejected on the basis of metal composition or mechanical properties, be sure that all test are verified. If necessary, have the verification made by a reputable commercial laboratory. This is particularly important if there is any doubt about the validity of test results or there is a dispute with a casting purchaser.

c. If the reason for rejection is dimensional, be sure that a relatively large number of castings have been examined by more than one inspector.

d. When variation in machining allowances are involved, determine if new machining fixtures are being used or a different method layout could have been used. (locating points)

e. The next step is to assess the initial or apparent area of accountability. For example; is the defect the result of:

   a. Molding problems; such as a crush, shift, cope raise, ram-off; swells; sand in the mold and so on.

   b. Does the defect appear to be related to core-making; such as a blow, erosion, broken cores.

   c. Is it a sand control problem; inclusions, washes, porosity, due to wet sand, hot sand, veining, buckles.

   d. Was the defect caused by pouring; was it a mis-run; was the casting poured short, or is the defect a cold-shut due to low pouring temperature.

   e. Another consideration is gating or feeding.

   f. Finally, was the casting defect caused by melting practice or a metallurgical deficiency i.e., Slag, soft or hard casting.

f. When the source of the defect is determined, the cause must be found and eliminated. This involves objectively reviewing every detail of the practices and procedures being used in the area of operation, suspected to be responsible for the casting defect. It is always well to remember that a casting defect, which is occurring in all castings produced, is usually associated with molding materials or melting practices. When the defect occurs only in a single casting, the cause can usually be traced to a change in the practice or technique used to product that one casting.

Put the occurrence of casting defects in the proper perspective.

For example, a typical gray iron production foundry will normally generate from 2.00% to 6.00% casting scrap. A jobbing foundry will often operate with scrap rates of up to 15% or more. This of course must be included in casting price.

At the present time, the majority of casting defects in production foundries are associated with molding and pouring. This is estimated to be about 85% of the total castings scrapped. The types of defects involved are:

1. Run-outs.
2. Poured-short.
3. Miss-run or poured-short.
4. Broken mold.
5. Crushes.
6. Sand in the mold; dirt.

These types of scrap are usually associated with people-problems, and to some extent, equipment maintenance. They can be controlled by aggressive supervision that understand casting production. Approximately 15% of casting scrap can normally be associated with:

1. Sand Control
2. Core Making
3. Melting Practices

These areas of foundry operations are often the least understood. When they get out of control, the result can be a major disaster, with the possibility of losing a days production or worse. This is why personnel working in these three phases of foundry operation require close and continuous supervision by knowledgeable supervisors.

A recent survey shows that there are 211 different categories of ferrous casting scrap. Of these, 42 are attributable to melting practices and melting materials. There are 126 types associated with core making and sand control. The balance of 83 categories of casting defects, are caused by molding, pouring, and cleaning. These are a few examples of what can happen when management does not give proper consideration to changes which occur in the overall scheme of operations.

Look at the following case histories to see what not to do.

- An example of improper definition of scrap was in a large production foundry. This foundry was owned by a large corporation, which utilized all of the latest and most modern management techniques such as computerized cost control, profit centers. And delegation of authority. In addition, the parent company promoted very hard and competitive interdepartmental management policies. This foundry had an on-going casting scrap level ranging from 8% to 22%. The alleged cause of scrap was attributed largely to the metal. This was done in spite of the fact that the iron produced always met both tensile properties and chemical composition requirements. The foundry had an excellent laboratory, which was used very effectively to control the melting operations.

  In spite of this, metallurgists and melting superintendents were hired and fired about once a year. Scrap meetings were a farce, gating problems, gas porosity caused by sand and cores, molding problems, venting, and so on were always attributed to metal by the collective management. Unfortunately, no matter how many metallurgists, and melting superintendents were hired, the scrap was not reduced. One day, someone in corporate management hired a foundry manager who was a foundryman and was able to put the scrap problem in its proper place. Now scrap levels are down to 3%. Another similar situation where no action was taken, that foundry is now closed. It is interesting to note that a recent survey shows that there are 43 types of ferrous casting scrap caused by melting practice and melting materials and approximately 152 kinds of casting scrap can be attributed to other causes.
- Blind emphasis on melting material costs alone, without consideration for quality, can result in disaster. There is a large gray iron foundry located in the east. This foundry produced castings for a very cost-conscious industry

where the mechanical properties of the gray iron produced are not considered important. There was no metallurgist. They did have a melting superintendent who operated a series of large electric furnaces. Laboratory facilities were adequate for controlling the melting operation and determining the mechanical of iron produced.

This foundry suddenly developed an ongoing scrap level of 20+% and was in the process of going broke. The causes of casting scrap were pinhole porosity, miss-runs, and low tensile properties (below the minimum of 25,000 psi). The problem was transient.

1. Some days there was no scrap.
2. Some days there was 60% scrap due to pinhole porosity.
3. Some days tensile properties were below 25,000 psi with pinholes.
4. Some days tensile properties were low and there were no pinholes.
5. There were also occasions when there were many castings scrapped because of mis-runs and cold-shuts.

The local management and a number of consultants attributed scrap to these causes:

1. The pinholes were attributed to wet sand, nitrogen from furan cores and improper venting. Efforts were made to improve sand control and Ferro-titanium was added to control the nitrogen problem. These efforts were unsuccessful.
2. The cause of low tensile strengths below 25,000 psi was attributed to a need for an alloy addition. An addition of copper resulted in no improvement. Addition of 0.3% chromium also did not improve the mechanical properties.
3. Unfortunately none of the conventional solutions worked. The problem was caused by the melting materials used. This foundry uses a furnace charge consisting of foundry returns and 50% cast iron scrap. An examination of the cast scrap used in the furnace charge revealed the presence of large quantities of cast iron fittings with leaded joints. There were also large quantities of aluminum-zinc die casting scrap mixed with the cast iron. In fact, streams of metal were seen running out of the pre-heaters. Layers from 6 in. to 12 in. of mixed aluminum, lead, and zinc, were found in the pit under the pre-heaters. Even though a large quantity of the non-ferrous metals melted off of the cast scrap in the pre-heater, a considerable amount remained in the scrap and was mixed into the cast iron. The result was that low tensile properties were caused by the presence of leas in the iron, which resulted in the formation of mesh graphite. Further investigation revealed that when castings contained 0.03% to 0.07% aluminum, pinholes occurred. As the aluminum content of the iron increased from 0.10% to 1.0%, the pinholes disappeared, but incidence of mis-runs and cold-shuts in the castings drastically increased. Shortly after the real casting scrap was revealed, a dependable and more expensive source of cast scrap was immediately found. Today scrap in this foundry is below 3%.

- The next example demonstrates how a commercial testing laboratory can cause a small steel foundry to scrap 20% of stainless steel produced. The foundry produces very precise shell-molded stainless steel castings used in extremely critical applications. The specifications are such that the mechanical properties of each heat required certification. About 25% of the tensile bars from so-called defective heats revealed that they were bent and apparently had been pulled in an unaligned position. This foundry is now using another testing laboratory and there has only been one heat of stainless steel scrapped since December 1976. This error, made by an inexperienced technician, cost the small foundry many thousands of dollars.
- There are many gray iron foundries that have intermittent and unexplainable chill control problems. Here is an example of what can happen: In this particular circumstance, there was a foundry producing thin section castings. The melting department was responsible for melting up to the tip of the furnace spout. The molding department assumed responsibility for inoculation of iron and pouring. No one paid any attention to pouring and inoculation. Casting scrap due chilled edges was over 20%. The iron pourer threw the inoculant on the foundry floor and not in the pouring ladles. There

was at least a foot of inoculant on the foundry floor in from of the melting units. The foundry was sold, and the new management has corrected the problem. It is amazing how often things like this happen.

- When the demand for metal in a ductile iron foundry over-runs the treating capacity, here is an example of what happens. The castings contained unreacted treatment alloy (5% magnesium ferrosilicon alloy). The problem was solved by installing another treating station and using a treatment ladle.
- This is what can happen when an overzealous engineer takes control: One man in a three-man holding crew on a large cope and drag unit was eliminated. Castings scrap due to crushes increased from 1% to 25% in one day. Later, the installation of a mold-closing unit reduced manpower requirements to one man.
- Here is an example of a change which caused a serious scrap problem: In steel foundries, nails are often used in cope and side-walls of large molds. The ails act as chills and reinforce the mold. A cost cutting representative from consulting firm said they were not necessary. The result was the loss of three days casting production. The moral is to try one and see what happens before changing everything.

Now For Some Good News

- There was a relatively small gray and ductile iron foundry which has been very successful and produced high quality castings. In fact, premium prices are paid for their castings because of the exceptionally high quality. This is particularly true with regard to dimensional tolerance, consistency of mechanical properties and chemical composition. The casting scrap in this jobbing foundry ranges from 2% to 6% for all causes. Castings scrap related to metallurgy and metallurgy practice is less that 1% of total scrap.

How is this done?

1. Competent experienced personnel are employed.
2. The causes of casting scrap are understood, recognized and controlled.
3. Well-defined melting practices have been established for each type of metal produced.
4. A small, but adequate, laboratory is used to control the melting practice.
5. First quality melting materials are always used. After all, metal cost are only 15% of the casting costs. So why take a risk for a very small saving?
6. Furnace charges are calculated.
7. Records of furnace charges, resulting chemical compositions and mechanical properties are recorded and analyzed on a daily basis for trends and variations.

This is what putting casting scrap caused by melting practice in proper perspective means. Metallurgical control of melting practices, which results in low scrap levels, can be achieved. Simply use good judgment and understanding in both large and small foundries. It also applies to all of the other phases of casting production.

Here are some of the more important, but often overlooked, causes of gray and ductile iron casting defects.

Gray iron is an iron-carbon-silicon, which contains an aggregate of graphite flakes. In order for the flakes to form, it is necessary for some types of nuclei to be present in the molten iron. These nuclei can come from many sources. Nuclei become smaller with time and temperature until they are not large enough to initiate a crystal growth, they are only an embryo. Nuclei can come from many sources:

1. Small particles of graphite from pig iron or cast scrap if the section size is large enough and cools slow enough to precipitate and grow a crystal of hexagonal structure large enough to pull carbon from the liquid iron and continue to grow.
2. Crushed graphite electrodes to nucleate graphitic carbon from the liquie iron.
3. The addition of inoculants.

If the molten iron does not have hexagonal nuclei present, graphite will form too late and the result will be carbidic iron and porosity.

Another factor, which must be considered simultaneously, is the fact that when gray iron solidifies, it expands in volume because graphite has 3.54 times the volume of iron. If fact, recent studies have shown an expansion of about 3% and a high cell count. What does this mean to a foundry man? It means that the furnace charge materials and inoculating practices drastically influence casting yield. This is true, both in electric furnace and cupola melting.

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To Promote the production and application of ductile iron castings
Issue 1, 2002

Thermal Analysis

Given at the Ductile Iron Society Meeting 6/14/01
By W.F, Shaw & B.T. Blatzer

The graphics in this article are imported from a Powerpoint presentation which was shown on a large projector. Some of them are not clear enough to clearly show the small numbers and text. If you would like a paper copy of this presentation, please email the Ductile Iron Society.

With this presentation being the first part of this session on thermal analysis, we felt it would be good to review a bit of the history behind this technique or tool that has been available for routine application for over 35 years. Let me first note that, while we often use the term "cooling curves", our preferred title for this topic is thermal analysis or TA, which we'll use for the rest of our presentation.

Well before the commercial development of TA for cast irons, it was used in studying solidification of all types of materials including cast irons, and one of the earlier references to its use was in Alfred Boyle's book, "The Structure of Cast Iron", published in 1946. Examples of two figures from that book are shown in **Fig. 1 and 2** (**Fig. 48 & 55** from Boyles). That work and most others over the years, however, utilized platinum/platinum rhodium thermocouples.

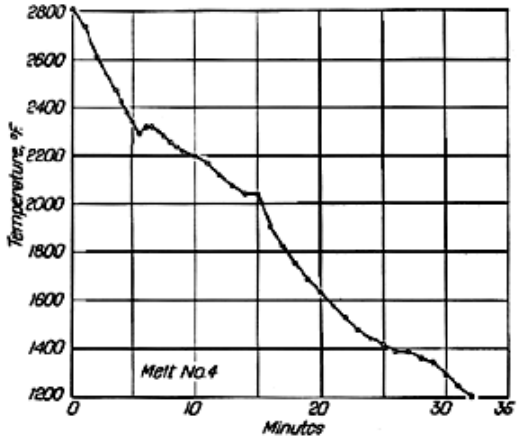


Figure 1 - Cooling curve of Melt No. 4

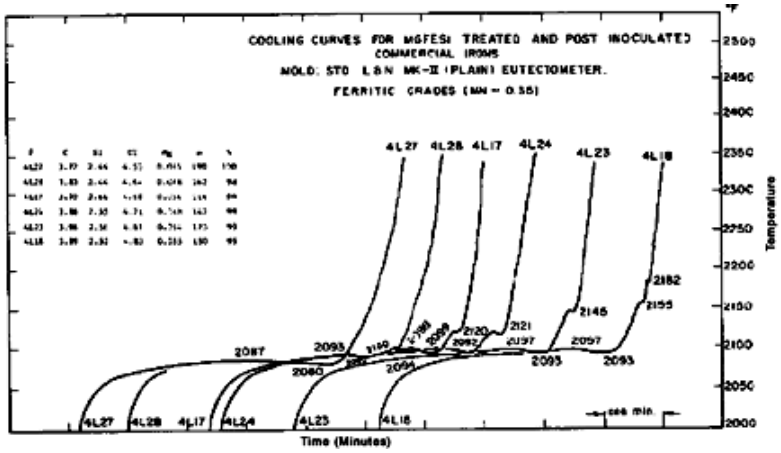


Figure 2 - Cooling curves of castings made from Iron No. 133. Curves on left from catings poured 2 minutes after inoculation. Curves on right from castings poured 32 minutes after inoculation.

The development of the currently used practice of low cost, expendable thermocouples was the outgrowth of work on risering by the Gray Iron Research Institute, our previous company name, in the 1950's during which they found that chromel/alumel rather than platinum/platinum-rhodium thermocouples could be used. The temperatures involved were actually above those typically recommended for chromel/alumel but this material was reliable due to the short exposure times. This work led to a rapid test for carbon equivalent based on the good correlation between carbon equivalent and liquidus temperature as shown in **Fig. 3 and 4**. Some similar work was underway at BCIRA about the same time, however they were still using platinum platinum-rhodium thermocouples & a somewhat larger sample mold.

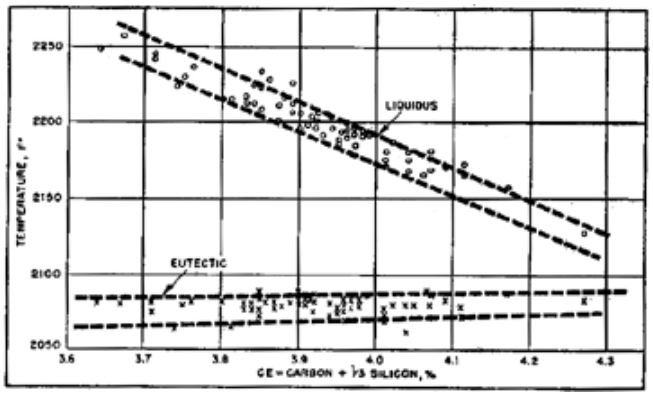


Figure 3 - Relationship is shown between liquidus and eutectic thermal arrest temperatures and carbon equivalent determined by chemical analysis.

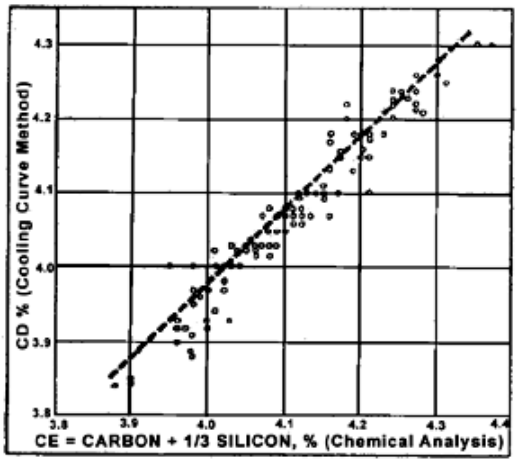
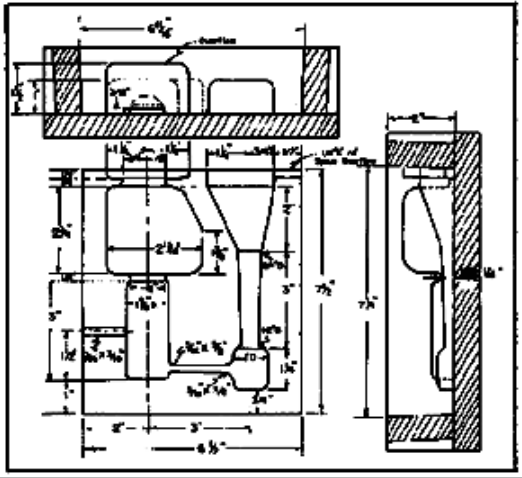


Figure 4 - Relationship of carbon equivalent data determined by cooling curve method and by chemical analysis.

The initial GIRI work involved oil sand cores with expendable thermocouple assemblies inserted as shown in **Fig. 5 and 6**. By 1962 there were 10 GIRI member foundries using this tool in production for measurement and control of carbon equivalent, obtaining CE values in less than a minute. The literature includes a number of articles on this topic by Dan Krause and Fred Kasch of GIRI. GIRI brought Leeds & Northrop into this work in the early 1960's which resulted in the development of relatively low cost shell mold expendable cups that evolved into the various types in use today. By the late 60's to early 70's there were about five TA cup manufacturers.



Carbon Equivalent - Cooling Curve Specimen
Core Box Detail
DWN by E.A.K. - March 20, 1961
1/2 Scale
Gray Iron Research Institute

Figure 5 - Carbon equivalent - Cooling curve specimen - Core box detail.

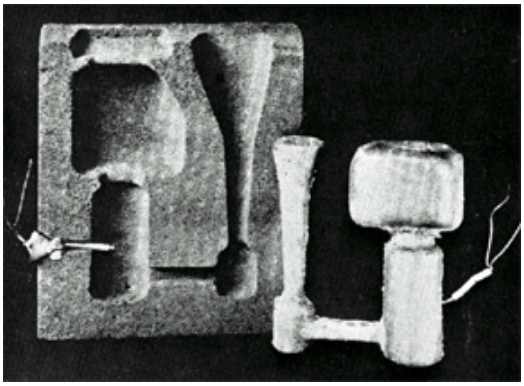


Figure 6 - Core mold and test casting.

Then in the early 1970's Alan Moore at BCIRA carried out further work that led to the fairly reliable calculation of carbon from TA curves utilizing the addition of tellurium to the cups. The tellurium caused the iron to solidify as white iron, providing a white iron eutectic temperature, which, combined with the liquidus temperature of the iron, allowed for rapid carbon calculation and even an estimated silicon analysis. This provided another highly useful tool for melting that almost all of you probably use today.

This also led, however, to some initial problems regarding reliability of this method. When L&N produced the first BCIRA Carbon Calculator (**Fig. 7**), it provided carbon values in North American foundries approximately 0.04% lower than combustion carbons from the same sample. This difference was confirmed during a joint visit to a number of our member plants by Dan Krause of GIRL and some BCIRA and Leeds & Northrop staff. They determined that the reason for this difference was due to the fact that the work by GIRI and other groups was based on the 1948 IPTS while the new BCIRA work utilized the new 1968 IPTS. This quickly resulted in production of a new carbon calculator for U.S. foundries as shown in **Fig. 8**. As far as I know, this potential problem was seldom, if ever, noted in the literature except in our reports, although today the option of 1948, 1968 or the newer 1990 IPTS scale is available on some TA units.

Figure 7

Figure 8

Although this problem was resolved, the different IPTS temperature scales continued to cause some problems since the U.S. iron and steel industry primarily retained the 1948 scale while most other countries have since converted to the 1968 or even the newer 1990 IPTS. In our temperature range, however, there are extremely small differences between the 1968 and 1990 scales.

We present this information today primarily to inform about this problem since it partly explains some of the differences in the equations, charts and graphs generated by various researchers as shown in **Fig. 9**. But foundry men should at least be aware of related problems when studying the literature or when checking instrument calibrations in your plants. Any such differences are minor in an application such as immersion temperature measurement but can be major in a thermal analysis application. An example of possible errors resulting from mixing the different IPTS scales is shown in **Fig. 10**.

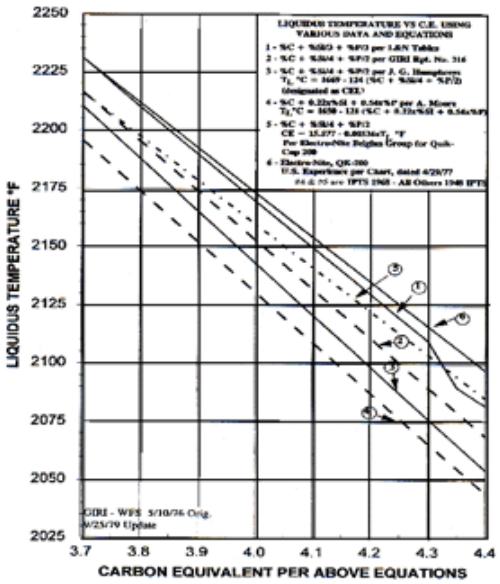


Figure 9

Temperature Variations From Differences in IPTS Calibration Between Type S Thermocouple and Instrument				
Instrument Calibration	1948	1968	1968	1948
Thermocouple Calibration	1948	1968	1948	1968
2000°F	2000	2002.7	1998.0	2004.5
2500°F	2500	2503.4	2496.0	2507.5

Figure 10

One other problem that arose after the BCIRA Carbon Calculator was that of insufficient tellurium in some of the TA samples caused by a number of variables. It was particularly evident in higher C.E. irons that are more difficult to chill and resulted in inaccurate white iron eutectic temperatures and thus errors in carbon analysis and even CE analyses, in some cases, since tellurium does increase liquidus temperatures by up to about 61°F We spent quite a bit of time in the 1970's and even the 1980's working with our member plants and cup suppliers on resolving this problem. One unique problem we ran into was a batch of cup receptacles in which both pins were the same alloy, either chromel or alumel. Once we figured out what it was, we immediately notified our plants and the supplier to make sure that they were replaced.

With the foregoing as background, let's briefly review some of the past work on TA applications for ductile iron, although we can only touch on a few examples. Our primary reasons for doing this are to, first of all, remind the younger industry personnel that there has been considerable research in the past and second, hopefully, to make all of you more receptive to continuing developments in this area. And perhaps third, we hope that some of you will be involved in the work that will further the application of this technique in production foundries. Research work on TA is interesting and helpful, but the real value is in its practical application.

You'll hear more about the ATAS system later in this talk and in the next two presentations. But for those of you who can't currently justify the cost of such a system, the following few examples from the literature and Bruce's information might stimulate you to use your current TA system to improve your metallurgical control. We are, by the way, speaking here about metallurgical "fingerprinting" as I've called it for many years via use of non-tellurium TA cups, not the conventional use of TA for chemical analysis measurement and control.

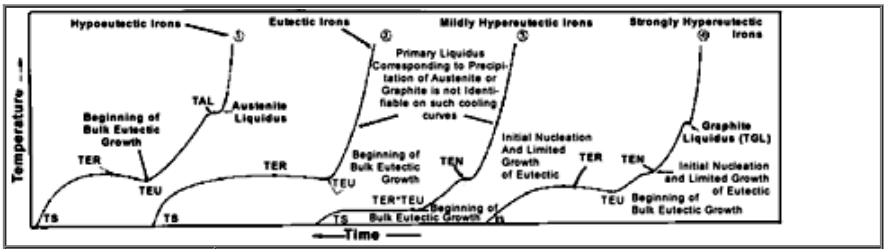
Two statements, however, are extremely important regarding plant applications. First, the use of TA methods for metallurgical control will not likely be of much help

unless you first have good chemistry and temperature control of your iron. And second, there are a number of potential errors in TA sampling and measurement that need to be eliminated or at least minimized in order to effectively utilize this technique, some of them highlighted in my earlier comments.

Let me preface our further comments by stating that ductile iron TA curves, except for base irons, are much more complex than those for gray iron, with considerable variation in their behavior both above and through the graphite eutectic region.

Note also that it's especially important when reviewing TA work by various authors to remember that each of them may have used different makes and sizes of TA cups as well as IPTS calibrations that would affect their results to some extent. For example, work by Gary Strong in the early 1980's used the smaller (Mark III) TA cups with vertical thermocouples while Heine's earlier work used the larger TA cups with vertical thermocouples while later work utilized the larger cups with horizontal thermocouples. Heine, Bradley et al also published some work in 1989 comparing the various types and sizes of TA cups and their relative cooling rates and other features.

Some fairly early work on Ductile Iron was reported on by Heine, Loper & Chaudhari in the 1974 AFS Transactions; they did TA work first on laboratory heats and then on commercial irons. **Fig. 11 through 13** present some TA definitions from that work plus a series of final ductile iron TA curve of commercial irons at two different manganese levels.



Key to Symbols used	Thus:
T - Temperature A - Austenite L - Liquidus E - Eutectic N - Nucleation U - Under-cooled R - Relalescence G - Graphite S - Solidus	TAL denotes the temperature at which primary austenite forms in hypoeutectic iron melts. TGL Denotes the temperature at which primary graphite forms in hypereutectic iron melts. TEN Denotes the temperature at which initial nucleation and limited growth of eutectic occurs. (This arrest is absent on curves 1 and 2 TEU denotes the lowest temperature to which iron melts undercool prior to beginning of bulk, eutectic growth. TER denotes the maximum temperature on eutectic arrest, which results from recalescence due to latent heat of solidification of eutectic phases. Often TER = TEU, as shown by curve 3 above TS denotes the solidus temperature for the alloy (Generally difficult to identify on eutectometer cooling curves) By definition (TEN - TEU) = Eutectic undercooling (TER - TEU) = Eutectic recalescence

Figure 11 - Typical eutectometer cooling curves illustrating the nomenclature used in text.

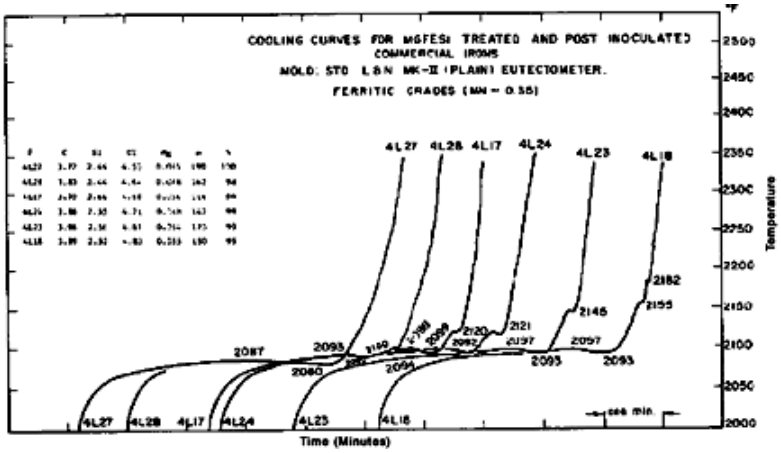


Figure 12 - Cooling curves for MgFeSi treated and post inoculated commercial

irons. Mold: (plain) eutectometer. Ferritic grades (Mn ~ 0.35).

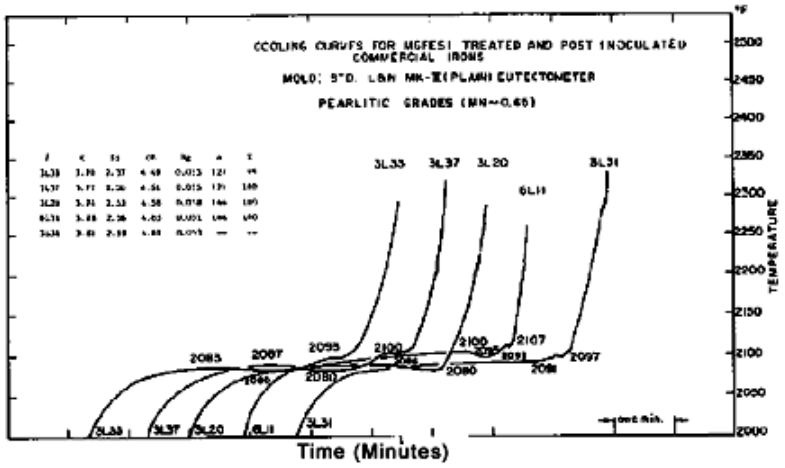


Figure 13 - Cooling curves for MgFeSi treated and post inoculated commercial irons. Mold: (plain) eutectometer. Pearlitic grades (Mn ~0.65)

A summary of just a few of their observations from that work is as follows:

1. Curves from good ductile iron typically exhibit relatively flat eutectic arrests followed by a rather steep tail end.

2. Nodularity generally increases with the amount of undercooling up to a point beyond which carbides tend to occur.

3. If TEU drops below 2075^{o}F or TER below 2085^{o}F, carbides and/or intercellular graphite occur, although carbides may be minimized in cases of high silicon contents.

4. TER for good ductile iron is typically about 40^{o} - 50^{o}F less than the calculated equilibrium eutectic temperature, TE.
(This suggests an optimum TER of ~2094^{o}F +/-5^{o}F @ 2.50% Si.)
TE, ^{o}F = 2117 + (11.7 X %Si)

5. Eutectic recalescence, TER - TEU, of over 15^{o}F is a clear sign of occurrence of vermicular, flake or irregular compacted graphite.

6. Nodule count increases with amount of eutectic recalescence, (or probably the nodule count determines the degrees of recalescence), but only up to a point beyond which non-spheroidal graphite occurs.

7. A high rate of recalescence between TEU and TER suggests high nodularity and nodule count. A slow rate may indicate presence of carbides.

8. Rapid cooling from 2050^{o}F on the curve is a sign that carbides are unlikely to be present. A cooling rate of about 20^{o}F/minute is typical of a carbide-free iron.

In the 1983 AFS Transactions, Gary Strong, a former student of Prof. Heine's, presented some practical applications of the earlier work by Heine and some of these are shown in **Fig. 14 - 16**.

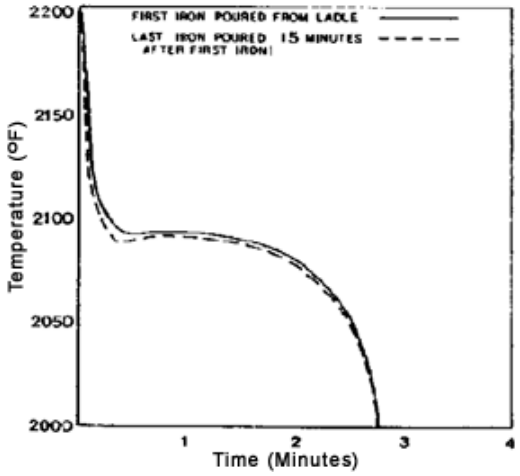


Figure 14 - Initial iron poured vs. last iron five minutes later.

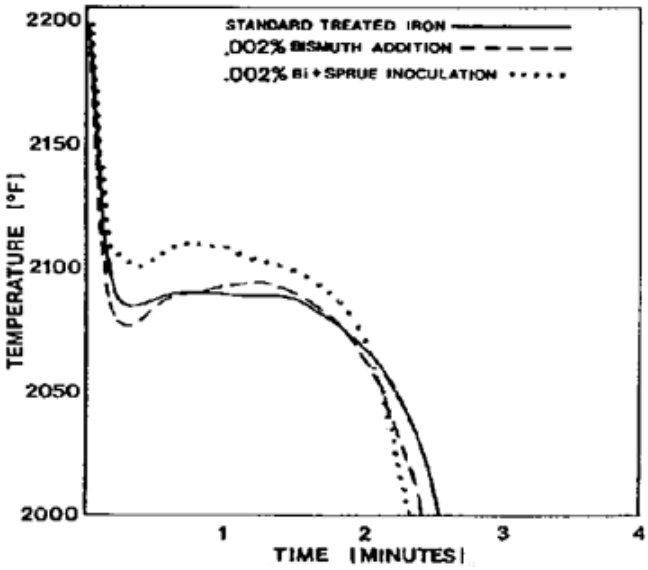


Figure 15 - Standard treated iron vs. bismuth and bismuth and sprue inoculation.

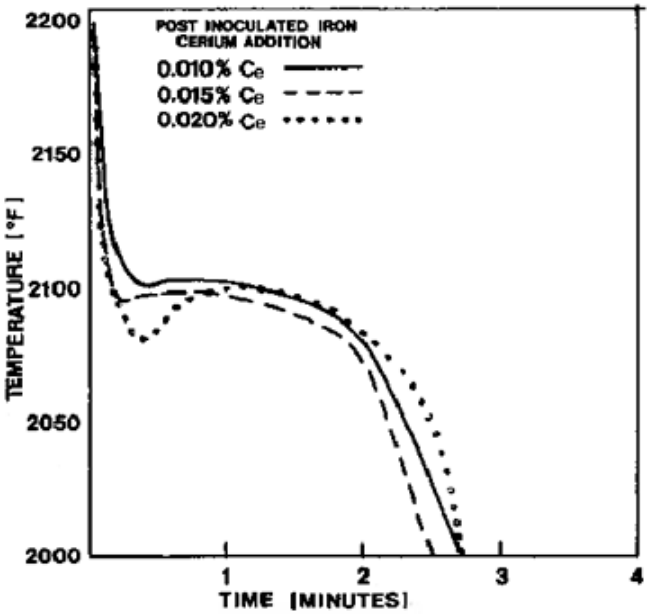


Figure 16 - Effect of increasing cerium in MG treatment on inoculated iron cooling curve.

A presentation by W. Knothe at the 1987 BCIRA International Conference put forth some interesting data and methods for process control and are summarized in **Fig.**

17- 23. These curves represent a shop using the Fischer process for ductile iron production. Of special interest to me was the fact that the author included statistical information with his TA curves, showing means and standard deviations for the various features of the curves. I'm unaware of any other papers providing such information.

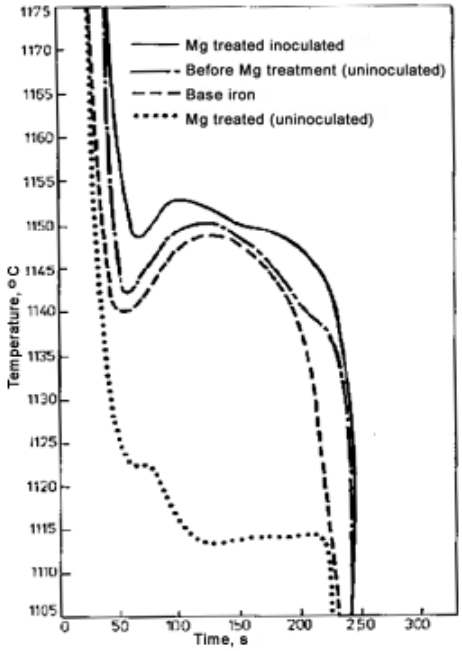


Figure 17 - TA Curves at each stage of a Fischer process Ductile Iron

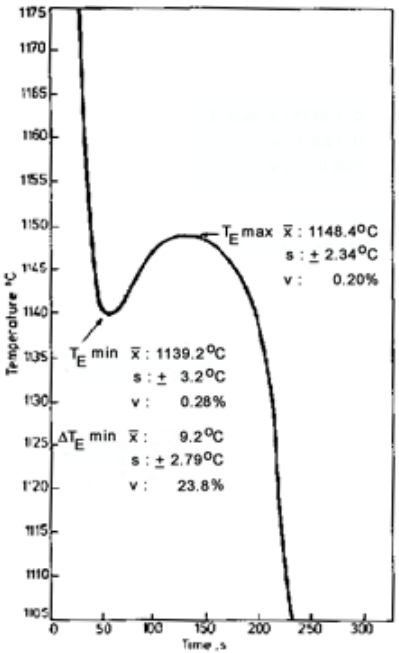


Figure 18 - Cooling curve of a composition adjusted base iron.

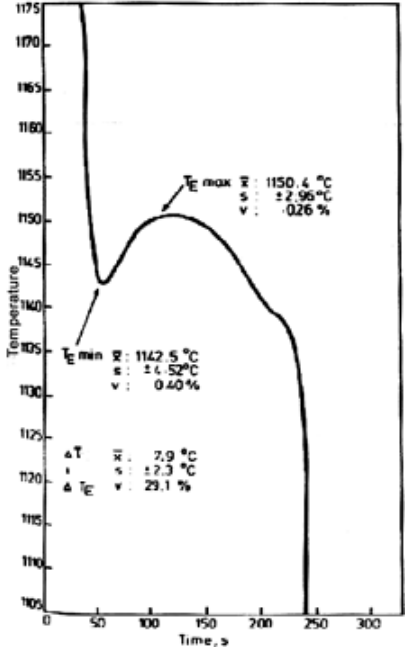


Figure 19 - Cooling curve prior to magnesium treatment in the Fischer converter.

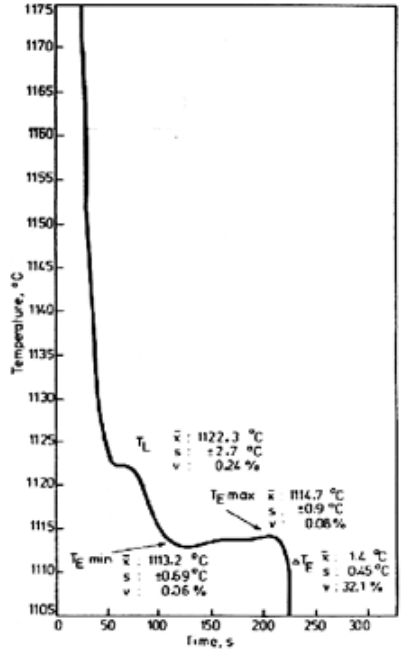


Figure 20 - Cooling-curve for an uninoculated magnesium-treated melt.

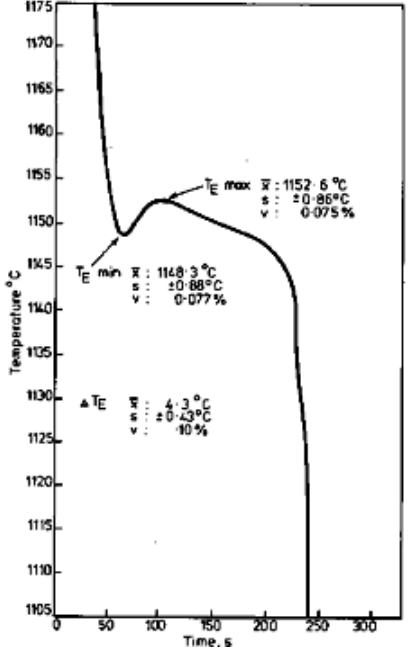


Figure 21 - Cooling curve of treated inoculated iron taken from the ladle just prior to pouring.

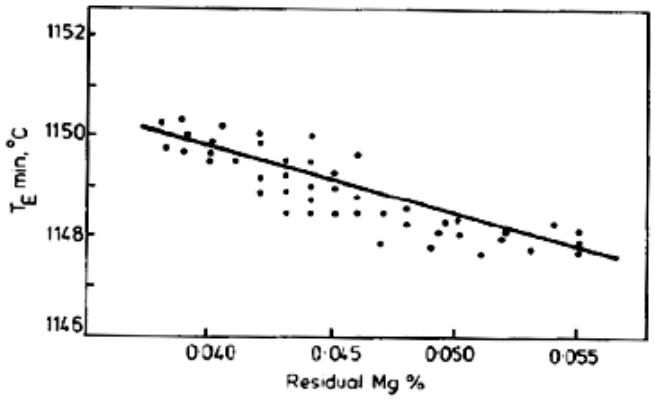


Figure 22 - Influence of residual magnesium content on TE.

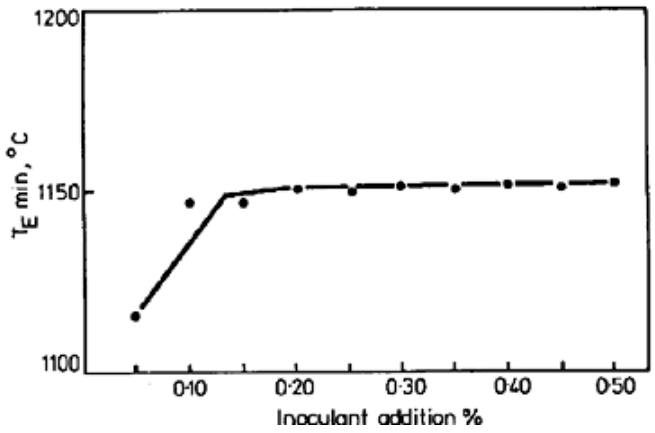


Figure 23 - Method used to establish the optimum necessary inoculant level.

A few years later, Heine and Bradley carried out further work at the U. of Wisconsin relating shrinkage to TA curve behavior on both lab and commercial irons. One of the early results of this work, comparing three production foundries, clearly confirmed that higher levels of manganese, chromium and magnesium promote low TEU temperatures, which in turn lead to increased shrinkage tendency. This led to subsequent changes in chemical analyses and process controls at the foundries which significantly reduced shrinkage related scrap. Other TA work by Hummer in Austria provided confirmation of some of these effects. And work by both Heine and

Hummer pointed out the effects of oxidation on TA curves, although Breeden of BCIRA refuted Heine's claims about oxidation in a 1982 report.

There are numerous other authors and papers we could refer to, but we hope that these few example of past work and Bruce's information will stimulate your thinking as to the potential benefits of TA process control. It's not a panacea for all of our problems, but it is a tool that, if wisely used, can be extremely useful.

Working in an industry where change is one of the few constants and quality demands are rapidly increasing, can we afford not to use all of the potential process control tools available to us? We can be sure that all or some of the following will change from time to time: charge materials such as steel, pig iron, coke and carbon raisers; ferroalloys, including inoculants, since they are produced with varying charge materials; and nodulizing and inoculating methods. All of these potentially affect our ductile iron process and the resultant metallurgy and consistency of our iron.

With the foregoing as background, Bruce Blatzer will now summarize some of the TA work on Ductile Iron that we've been doing with our member companies, although recently we've been doing more with Gray Irons. It's far from complete or exhaustive, but we feel that we need to continue encouraging our members and our industry to use every tool available to improve the consistency of our iron and castings.

Thermal Analysis article Part 2

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Ductile Iron News
Ductile Iron Society
To Promote the production and application of ductile iron castings
Issue 1, 2002

Thermal Analysis - Part 2

Given at the Ductile Iron Society Meeting 6/14/01
By W.F, Shaw & B.T. Blatzer

Before I get into the ATAS testing I want to show some TA data we collected a few years ago to illustrate how TA data can be used as a metallurgical fingerprint and this fingerprint can be used to compare iron produced during different time periods and different conditions.

Representative TA Data
Ductile Iron - C5-3 + 75% FeSi
1996

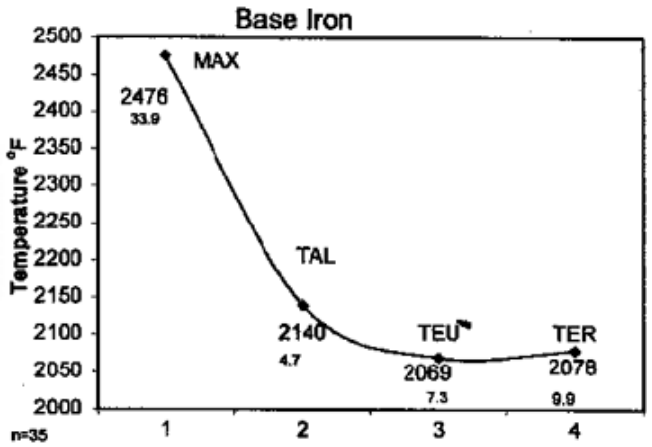

Figure 24 - Plotted values are averages. Values in smaller font are standard deviations.

Figure 24 shows statistics from a series of 35 non-tellurium cup samples poured from a base Ductile Iron. There is no meaning to the shape of this curve, rather it only provides a convenient means of looking at the average and standard deviation of any number of samples. The curve was produced by entering the average arrest temperatures into a spreadsheet, plotting the points and connecting the points with a smoothed curve. At the time we only monitored four temperatures, the maximum temperature of the sample (MAX), the liquidus (TAL), the undercooling (TEU) and the recalescence (TER). The reason we track the maximum temperature is to get a feel for the consistency of the sampling, which we think has some effect on the results. The next slide, **Figure 25** shows the same iron after inoculation with CS-3 and 75% FeSi. We use the standard deviations of each of these temperatures to determine the consistency between the base and final irons. Here it is difficult to tell which is more consistent due to two arrest temperatures having higher standard deviations for the final iron and two arrests having higher standard deviations for the base iron.

Representative TA Data - Ductile Iron - C5-3 + 75% FeSi - 1996

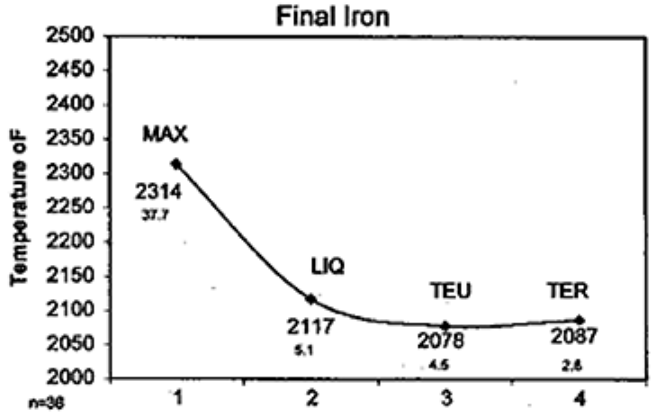

Figure 25 - Plotted values are averages. Values in smaller font are standard deviations.

Representative TA Data
Ductile Iron - C5-3 + Vaxon
1996

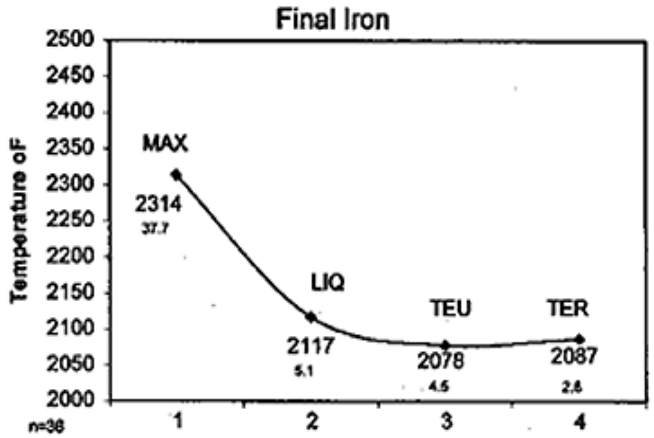

Figure 26 - Plotted values are averages. Values in smaller font are standard deviations.

Representative TA Data - Ductile Iron - C5-3 + Vaxon - 1996

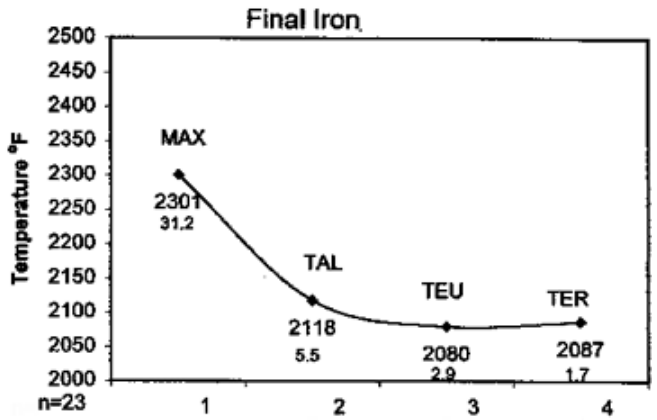

Figure 27 - Plotted values are averages. Values in smaller font are standard deviations.

The next two slides, **Figures 26-27**, show the same type of information for a time period using a different inoculant. Here the final iron is more consistent on the average as shown by the lower standard deviations of the arrest temperatures. **Figures 28-29** show the same base and final averages as the previous sets of slides, but for a different time period. The final iron is more consistent here as well.

Representative TA Data - Ductile Iron C5-3 + Vaxon
8/2 - 8/29/95

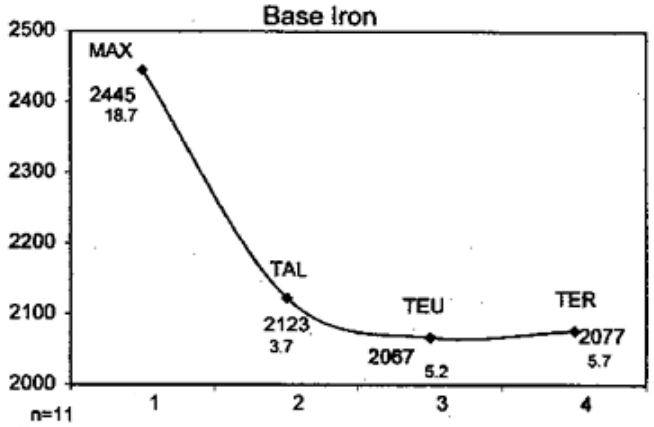

Figure 28 - Plotted values are averages. Values in smaller font are standard deviations.

Representative TA Data
Ductile Iron C5-3 + Vaxon
8/2 - 8/29/95

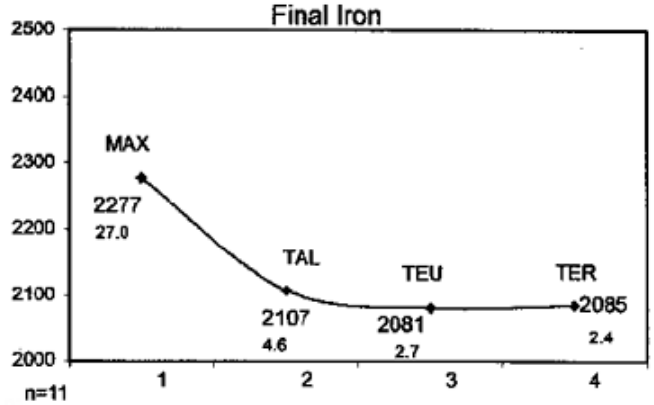

Figure 29 - Plotted values are averages. Values in smaller fonts are standard deviations.

Here on the next slide, **Figure 30**, the averages from the previous curves are displayed to make it easier for comparison. It appears that the irons poured during 1996 were similar in terms of all four temperatures, but the iron from a period in 1995 was somewhat different as shown by the lower max and liquidus values for the base as well as the final iron.

Comparison of Inoculants and Time Periods						
	C5-3 + 75% FeSi Avg. '95		C5-3 + 75% FeSi 1996		C5-3 + Vaxon 1996	
	Base	Final	Base	Final	Base	Final
MAX	2445	2277	2476	2314	2472	2301
TAL	2123	2107	2140	2117	2136	2118
TEU	2067	2081	2069	2078	2068	2080
TER	2077	2085	2078	2087	2076	2087
Degrees F						

Figure 30

A few months ago we finished testing with an ATAS unit in five of our member foundries. 1 would like to share some of the preliminary results. Five separate foundries decided to participate in this testing. Four of these foundries make large castings with section thicknesses of 3-4 inches and larger. All of the testing was done with Ductile Iron only.

We initially established some project goals which you see here. We knew from

some of our other member's experiences with the ATAS unit that it could determine metallurgical properties of small castings, but we did not have any experience with large castings. Although shrinkage is not much of a problem with large castings, we wanted to see if the ATAS unit could predict when the iron would be more shrink prone.

The next slide shows the test plan we tried to follow for a period of six weeks. The first thing we did after training melting personnel in how to identify samples was to pour a lot of samples to build a history of normal iron. We also poured test castings at some of the foundries.

Before showing the data I want to review a few definitions of acronyms so that everybody will not wonder about the terms they will see on the next few slides.

One of the foundries participating in the test program tested the ATAS unit for two different time periods. This gave us the opportunity of comparing the iron fingerprint for both of these time periods to see if anything had changed. **Figure 31** shows that irons from these two different time periods were essentially the same.

Comparison of Two Time Periods - Same Plant

Base	MAX	TL	TE low	TE high	S1	GRF1	GRF2	TS	n
1st period	1388.7	1165.0	1141.6	1148.5	27.4	70.1	58.4	1095.3	22
2nd period	1396.1	1167.0	1136.9	1144.2	32.1	61.8	67.4	1093.2	20
Treated									
1st period	1357.8	1159.0	1140.5	1144.9	27.9	67.0	121.5	1093.5	22
2nd period	1367.8	1158.7	1141.2	1145.2	28.3	72.6	99.0	1094.2	15

Figure 31

Figure 32 shows the results from base samples taken at each foundry. Notice there is a similarity among the foundries in terms of averages, but some of the foundries were more consistent than other as measured by their standard deviations.

ATAS Project Base Ductile - Comparison

Foundry Obs	247 29 obs		328 42 obs		633 50 obs		159 14 obs		515 50 obs	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std	Avg	Std
TL ^{o}C	1179.2	22.4	1183.3	5.9	1187.9	20.7	1168.7	4.4	1165.8	4.7
TE low ^{o}C	1140.1	4.2	1144.6	2.3	1141.4	4.4	1135.8	3.2	1141.4	3.1
R	4.7	1.4	5.9	1.0	6.7	1.2	7.4	1.2	6.5	1.7
S1	34.1	12.3	35.7	2.5	37.9	8.9	33.2	2.1	28.4	3.2
GRF1	63.1	12.8	63.8	7.0	62.4	13.9	65.7	5.4	68.3	5.7
GRF2	33.7	10.8	31.2	9.9	41.1	23.0	35.4	11.0	61.2	16.0
dT/dt TS	-3.4	0.6	-3.6	0.5	-3.2	0.7	-3.4	0.7	-2.6	0.3
TS ^{o}C	1104.4	5.2	1106.8	7.0	1104.7	8.2	1101.0	5.8	1093.8	7.1

Figure 32

When we looked at base parameters compared to treated parameters we were interested in consistency again. As you can see from **Figure 33** which shows the details from one of the participating foundries, some of the treated iron parameters were more consistent and some were less consistent. if we had taken fully inoculated samples we would have expected parameters that were more consistent than either those from base or treated irons.

Base vs. Treated Comparison

Type	Base 29 obs		328 42 obs	
	Avg	Std	Avg	Std
TL ^{o}C	1179.2	22.4	1153.5	5.7
TE low ^{o}C	1140.1	4.2	1140.4	7.9
R	4.7	1.4	4.2	2.1
S1	34.1	12.3	23.2	8.0

GRF1	63.1	12.8	65.9	16.7
GRF2	33.7	10.8	98.0	25.9
dT/dt TS	-3.4	0.6	-2.1	0.3
TS ^{O}C	1104.4	5.2	1097.7	13.5

Figure 33

The next slide **Figure 34** shows the treated Ductile results from four of the five foundries that participated in the testing program. One of the foundries did not pour any treated samples. It is important to note that most of the inoculation for this iron was from in-the-mold inoculants and our sampling was from freshly treated iron. The rightmost column shows the target levels for these selected parameters for shrink and chill free iron according to the ATAS documentation. As can be seen some foundries fared better than others in attaining the target values.

ATAS Project Treated Ductile Comparison						
Foundry	247	328	633	159	515	Target for shrink free and chill free iron
Obs	29 obs		12 obs	13 obs	26 obs	
	Average		Average	Average	Average	
TL ^{O}C	1153.5		1150.4	1140.3	1158.7	low
TE low ^{O}C	1140.4		1143.3	1138.9	1140.8	high
R ^{O}C	4.2		0.9	3.7	4.3	2 -3
S1	23.2		22.8	4.6	27.7	very small
GRF1	65.9		100.5	109.7	68.3	> 100
GRF2	98.0		45.3	98.9	119.6	< 40
dT/dt TS	-2.1		-3.1	-2.2	-2.0	< -3
TS ^{O}C	1097.7		1101.4	1092.3	1094.2	high

Figure 34

The test phase is now complete, there is some analysis work yet to be done before we can make our final conclusions. We learned much in terms of metallurgical consistency of the iron and look forward to working with this unit more in the future.

We learned

1. TA data can be used to compare the metallurgical condition of iron from one time period to another.
2. New charge materials, alloys and inoculants can be evaluated using TA data.
3. There are metallurgical differences in irons produced at different foundries.

To make the most of thermal analysis as a metallurgical tool we recommend collecting process information that can be correlated with TA data. This means that foundries should be monitoring and storing this information electronically so that when changes are noticed, time will not be wasted entering data into a computer; the data will already be there. A list of the minimum type of information that is necessary for this effort can be seen in this slide.

In conclusion, we believe that thermal analysis is another tool that foundry men can use to control the metallurgical consistency and properties of irons they produce. We have encouraged our members to incorporate TA in their process controls for many years and with the development of the ATAS and other TA products we are renewing our efforts to encourage the use of this technology.

Part 3 of Thermal Analysis
Suggestions for Improved Reliability in Thermal Analysis of Cast Irons

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To Promote the production and application of ductile iron castings
Issue 1, 2002

Thermal Analysis

Suggestions for Improved Reliability in Thermal Analysis of Cast Irons

1. Liquid Iron Sampling - uniformity & consistency are mandatory

   a. Make sure the sample ladle is free of iron and slag and is as hot as practical.
   b. Don't use graphite or clay-graphite ladles for sampling since they tend to produce some inoculating effect.
   c. Make sure the iron being sampled is as close to the same temperature as possible from sample to sample. (Note that this temperature will vary depending on whether it is a furnace or ladle sample.)
   d. For electric furnace samples, best results are usually obtained once a temperature of ~2700^{o}F has been reached in the furnace.
   e. If sample ladle is filled from another ladle, we recommend filling the sample ladle, emptying it and refilling before pouring your sample.
   f. Make sure the cup stand is kept as clean as possible, free from resin build-up and spilled iron, out of any cold drafts and at as constant a temperature as possible.
   g. Make sure the cup and stand are level, not tipped, and that the cup is poured completely full.
   h. If frequent samples are poured (more than ~4-5/hr.), use a second stand and alternate between stands to prevent overheating of the stand.
   i. Good sampling practice will result in consistent maximum temperature at least 50^{o}F to 100^{o}F above the liquidus temperature.
   j. When pouring final iron samples, allow at least two minutes after inoculant addition before pouring your sample.
   k. Remove the sample from the cup stand as soon as analysis is completed to minimize resin build-up and to permit the stand to cool prior to the next test.
   l. Regularly clean the cup stand and contacts with a wire brush or other means.

2. Equipment Calibration

   - from the cup all the way back to the instrument - extremely important!! (Be aware of variations between IPTS thermocouple standards. Cups for the N. American foundry industry are 1948 IPTS. Do you know whether your instrument is being calibrated per 1948, 1968, or 1990 IPTS?)

Table showing errors between IPTS 68 and IPTS 48 and also the temperature differences which exist if IPTS 48 thermocouples are used with IPTS 68 instruments.

(From 9/23/81 memo from L.R. Jones/E-N to W.F. Shaw)

Temp ^{o}F		Instrument 68/TC 48	
IPTS 68	**IPTS 48**	**Temp ^{o}F**	**T^{o}F**
2000	1997.3	1995.5	4.5
2100	2097.1	2095.4	4.6
2200	2196.9	2195.1	4.9
2300	2296.8	2294.9	5.1
2400	2396.7	2394.0	6.0
2500	2496.5	2492.5	7.5

3. Cup purchasing, storage & monitoring

   a. Purchase cups in large quantities (obviously based on your usage) with the specification that all cups in each order be from the same manufacturing lot.
   b. Store cups in as warn and dry an atmosphere as possible. If stored in a cold warehouse, make sure cups are brought up to room temperature well in advance of their usage.
   c. Before using a new lot number, compare TA curves from current vs. new lot of cups to ensure that no significant differences occur.
   d. Include the supplier's lot number on your melt records & note when a change in lot number occurs.

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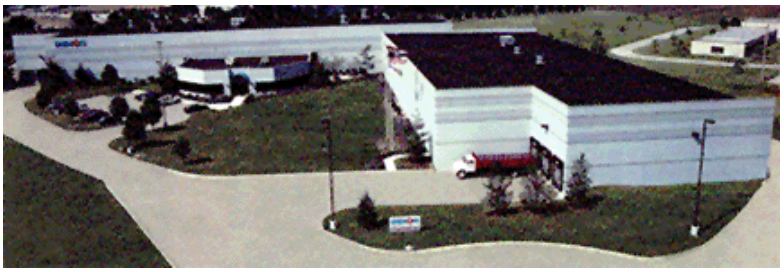
Associate Member Profile

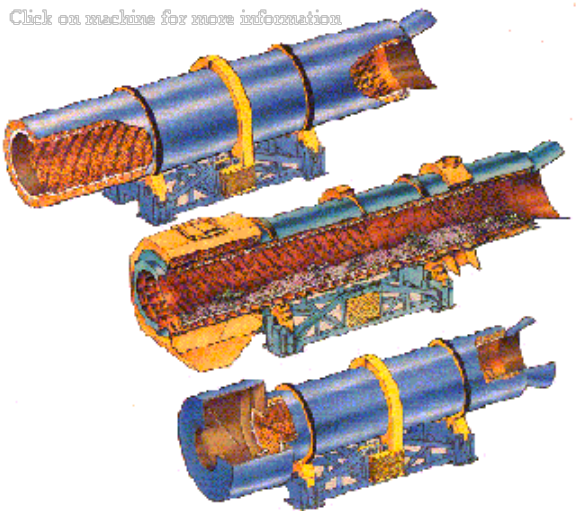


Didion International, Inc.

Designers, Engineers, Manufacturers

Company Profile - The Didion family has been in the foundry industry since 1875. DIDION, the Machinery Company, was founded in 1974 when Charles J. Didion, a third generation foundryman, realized the inherent pitfalls in vibratory shakeout systems and developed DIDION Rotary Processing Machinery. His numerous inventions revolutionized shakeout, reclamation, sand screens, casting cleaning/cooling and the sand blending/cooling needs of the foundry industry. The equipment was patented internationally and the company has grown to include over 900 machines in 42 countries worldwide. The high efficiency design, reliability and low maintenance requirements of every DIDION machine has turned the company into the world leader in Rotary Processing machinery - saving customers throughout the world hundreds of thousands of dollars annually.

Rotary Equipment



Rotary Sand/Casting Separator

Poured molds enter drum. Sand is quietly and efficiently separated from

castings, sand pockets emptied, and gates and external cores removed.

Rotary Media Drum

Castings and sprue then enter the rotary media drum. Cling sand is scrubbed off resulting in clean castings and returns, eliminating or greatly reducing shot blast time. Cleaned castings are cool enough to handle with gloves, and can be inspected prior to grinding.

Rotary Protective Coating Drum

Cleaned castings enter coating drum where special liquid bath further reduces temperature for easier handling while thoroughly coating parts with a rust inhibitor.

Rotary Lump Crusher/Sand Reclaimers

The most efficient and reliable lump crushers/sand reclaimers in the industry.

Rotary Dryers

Totally reliable technology for drying a full range (and sizes) of materials. Uniquely designed to provide optimum product exposure to incoming heated air, it also maintains temperature uniformity with a variable Jet burner.

Rotary Sand Screens

Blends, conditions, and removes core butts and tramp metal from return sand in one easy step.

These Machines Leave Our Competitors Shaking

It's time to quit shaking and get on a roll. Take a look at DIDION'S line of Rotary Processing Equipment, the one's with the fastest pay-back time in the industry. Usually within six months or less.

This revolutionary equipment conditions green sand, no-bake and shell moulding, while it cleans brass, bronze, ductile, gray, malleable, or steel castings.

DIDION Rotary streamlines your operation and eliminates that cleaning-room bottleneck. It also means no more airborne silica dust, providing a safer and cleaner environment.

Available in ten standard sizes or custom designed for special applications, DIDION Rotary is more efficient, economical and reliable than vibrating shake outs, and we have the customer testimonials to prove it.

Take the three machines pictured above. Used individually or integrated into a fully automatic system, this equipment will clean large or small castings, as well as, condition and screen the sand more efficiently than any other equipment available. And, in less time using less space

Installation is easy too, no pits or special foundations. In most cases, all you need is a weekend. As for maintenance, your mother-in-law could handle it. All parts are off-the-shelf, meaning no more shut-downs and less labor.

Now you know why our competitors are shaking. They don't have a choice. You do. Pick up the phone now and get on a roll. It's pay-back time.

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News Briefs

MEETINGS

The **Ductile Iron Society Annual meeting** is scheduled for June 12-14, 2002 including a tour of Precision Metalsmiths, Inc. in Markesan, WI.

The **World ADI Conference** will be held on September 25-27, 2002 at the Galt Hotel in Louisville, Kentucky.

The **June 2003** meeting has not been scheduled yet.

There will be a **Keith Millis Symposium** on October 20-23, 2003 at the Crowne Plaza Resort in Hilton Head Island, South Carolina.

BUSINESS

Dublin, Ohio (USA) - The Foundry Products Division of **Ashland Specialty Chemical Company**, a division of Ashland, Inc., has reached agreement with **Xsilogy, Inc.** to collaborate in developing and marketing software applications for real-time, wireless, Web-based monitoring of foundry processing equipment. The solutions that Ashland will bring to the marketplace will integrate versatility and efficiency gains into foundry processes to reduce costs, increase production yields, and achieve environmental compliance as well as other benefits.

Troy, Mich., March 6, 2002 - Researchers and engineers from **INTERMET** Corporation, one of the world's leading independent manufacturers of cast-metal automotive components, presented three technical papers on new advancements in material, process and testing technology at the SAE World Congress in Detroit.

Presenters from INTERMET's Technical Center in Virginia as well as from the company's engineering office in Troy, Michigan, introduced an evaluation of magnesium alloys in structural and high-temperature applications; an innovative study on how design and material properties interact during the testing of ductile iron brake parts; and new developments in hardened ductile iron powertrain components.

TROY, Mich., January 7, 2002 - **INTERMET** corporation, one of the world's leading independent manufacturers of cast-metal automotive components, announced today that during 2001, it had been awarded new business worth a total of $400 million. The new contracts are for programs slated to run through 2006 and consist of components to be manufactured in aluminum, magnesium and ductile iron for automotive powertrain, chassis/suspension, and interior applications. INTERMET customers for these programs include automakers and Tier-1 system suppliers.

TROY, Mich., January 21, 2002 - Chassis components produced by **INTERMET** Corporation are providing strong support for the 2002 Chevrolet TrailBlazer, which was named the North American Truck of the Year by a panel of distinguished automotive journalists at this year's North American International Auto Show (NAIAS).

PEOPLE

Milwaukee, Wisconsin - Grede Foundries, Inc., has appointed Bill Riner as Vice President - Operations at its St. Cloud foundry in St. Cloud, Minnesoty, and named **Tam Trudeau-Ebenhoeh** as Works Manager at its Vassar foundry in Vassar, Michigan.

CLEVELAND - Foseco Metallurgical Inc., a leading provider of proprietary products and systems designed to enhance quality and efficiency ion aluminum, iron and steel foundries has promoted **Daniel C. Salak** to Vice President of Sales.

Salak has been with Foseco Metallurgical, Inc. since 1976 and has previously held several sales management positions. prior to his recent promotion, Salak was Marketing Manager for Feeding Systems in North America. In his position as Vice President, he will be responsible for the direction of all Foseco Metallurgical, Inc. foundry salespeople and distributors of Foseco Metallurgical, Inc. products in the United States and Canada. He will be based in Foseco Corporate Headquarters in Cleveland, Ohio.

Milwaukee, Wisconsin - Grede Foundries, Inc., has appointed **Paul M. Ward** as Vice President of Operations at its Wichita foundry in Wichita, Kansas.

Ward joined Grede Foundries in June 1972, shortly after graduation from the University of Wisconsin - Madison, with a BS degree in Nuclear Engineering. After several assignments at various Grede plants, he became Vice President, Operations at its Iron Mountain foundry in Kingsford, Michigan. Most recently, he served as Vice President, Operations at its St. Cloud foundry in St. Cloud, Minnesota.

ESD The engineering Society and the Affiliate Societies are celebrating Engineers' Week by hosting the 31st Annual Gold Awards Banquet on Wednesday, February 20th at 6:00 p.m. at the Marriott Dearborn Inn. This event is a joint effort of over 45 Affiliate Societies to honor those in our community who have contributed to promoting the engineering and scientific professions, and provided a positive contribution to our community through their volunteer work. This year's Gold Award recipient is **Mr. John R. Keough, P.E.** Mr. Keough along with ESD The Engineering Society would like to extend an invitation to you to join us at this annual event.

Dublin, Ohio (USA) - Ashland Specialty Chemical Company's Foundry products Division has named **Dr. Jiang Fu** and **Ruben**

Bake to the newly created positions of market development managers. Michael W. Swartzlander, vice president and general manager of the division, made the announcement.

Fu and Bake will be working for the division's senior management assisting in developing and implementing various global strategic initiatives. They will be based in Dublin, Ohio, and report to Swartzlander, who said, "Jiang Fu's experience in all aspects of our recent start-up and initial operation of our wholly owned company in China, as well as his in-depth understanding of metal casting, will be leveraged in evaluating and pursuing additional opportunities for serving our global customers. Ruben Bake brings significant global marketing and sales experience in a variety of industries to our business. We look forward to their assistance and contributions to the Foundry Products Division's management team in strengthening our capabilities and reach to metal casters worldwide."

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