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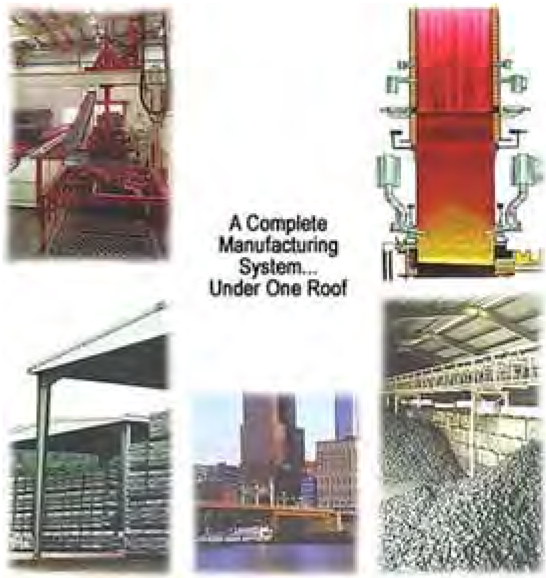
Overview of the Silicon Carbide Market



Overview of the Silicon Carbide Market

By Gustov O. Hughes

Abstract
Silicon carbide is a versatile, useful, manmade material. It is made by blending coke and sand and applying heat. The North American market has grown significantly while a large part of it is now imported. The major users of silicon carbide grain are the abrasive, refractory, and alloy industry. The iron foundry industry uses a significant amount of silicon carbide in the form of refractories and alloy additions. Trends in the market point to stable to slightly decreasing pricing for SiC in the near future.

Silicon Carbide Production
Silicon carbide is a black to green material that is a combination of 70% silicon and 30% carbon. In nature, only a small amount exists, where coal and sand have been exposed to each other in the presence of a significant amount of hear. No commercially viable deposits exist, so for practical use, the material is manufactured.

To make silicon carbide, usually low sulfur petroleum coke and high purity sand are selected as the raw materials. In some cases, coal is used in place of petroleum coke, though this tends to have a negative affect on properties as well as pollution problems. The standard method for producing SiC is in a electrical resistance furnace. The coke and sand are mixed together and an electric current is run through the material. The resistance of the blend creates a significant amount of heat that drives the reaction:

$$2\ SiO_2 + 3C + heat = 2SiC + CO\ (Gas)$$

The core of the arc will generate the highest purity silicon carbide, with the further from the arc, the lower the grade becomes.

Properties
The properties of silicon carbide make it a useful material for several different manufacturing processes. It is very hard, a 9.1 on the Moh's hardness scale. It has a very high resistance to heat, in reducing conditions subliming at approximately 2700^{o}C. Though very hard, it is also very brittle, making it difficult to keep large pieces together.

For a ceramic material, SiC also has a couple of unique properties. It has a very high degree of volume stability through a wide temperature range. It also has a very high thermal conductivity. A combination of these two properties will make a body composing of SiC very resistant to thermal shock stresses.

Chemically, SiC is a very non-wetting material, giving it high resistance to many molten slags and metals. Since the slags do not coat the SiC well, it inhibits any reactin.

Abrasive Applications
The initial use for silicon carbide is in the abrasive industry. With a hardness between that of corundum and diamond, SiC makes an excellent abrasive material. Many sandpaper and abrasive wheels take advantage of this property.

For the abrasive industry, the most important property is purity. The higher the SiC content the harder the material. Bulk density of the SiC, which can be affected by the manufacturing process, is also important.

SiC in Refractories
SiC is useful in refractories because of its high resistance to heat, its low thermal expansion, its high thermal conductivity, and its low wetability to many types of metals and slags. The properties that a refractory design engineer will look at in a particular SiC material vary somewhat for different applications. A general list of important properties for refractories are listed here:

1. SiC Content
2. Moisture Level
3. Magnetic Level
4. PH
5. Acid Compatibility
6. Particle Size
7. Accessory Oxide Type and Content

In the foundry industry, there are several important uses for refractory grade silicon carbide. SiC is often added to iron runner and cupola repair materials, as well as to cupola refractories and occasionally in induction furnace linings.

Outside the iron industry, silicon carbide containing refractories are often found in red metal applications, kiln furniture, blast furnace runners, tapholes and boshes, and in heat exchange units.

SiC as an Alloy Addition
On a volume basis, the largest use of silicon carbide is as an alloy addition. On a silicon unit basis, SiC is a very competitive source of this important element. Compared to many of its competing sources of silicon such as ferrosilicon or silvery pig, it is very low in accessory oxides. It also has other advantages compared to these materials such as a deoxidation affect and a pre-inoculant affect. In the steel industry, SiC is a more efficient fuel source than ferrosilicon.

In the iron industry, SiC is used in two ways. One is as an additive to induction furnaces and the other is as an additive to cupolas. In induction furnaces, the material is usually added as crude grain of 90% SiC purity level. In cupola applications, grain would tend to fly into the dust collector; so briquetted silicon carbide is used.

For induction furnaces, several factors should be considered before choosing the grain used. The first is the actual SiC content of the grain. Obviously, the higher the SiC content, the more available Si for the melt. The moisture content is important, with lower being better. Besides the safety issue of adding moisture to a molten metal, the operator should not expect to pay for water since it is not needed in this case. The particle size is also important, with excess fines tending to lead to lower recoveries.

Another chemical factor besides the SiC content is the amount and type of accessory oxides that are present. The preferred elements present in the non-SiC part of the material are carbon and silica. The three most common other elements that could cause problems are nitrogen, sulfur, and alumina content.

Nitrogen, of course, can cause casting problems due to nitrogen porosity if found in excessive amounts. Earlier shipments from China were reported to contain very high amounts. Three shipments from China tested by Leco Laboratories in 1999 averaged 0.14% nitrogen. This is still about twice as high as reported numbers for domestic material but probably below the threshold where nitrogen porosity is considered a factor. Nitrogen levels of Russian and South American materials were tested in the 0.97% area, about the same as reported domestic numbers.

Sulfur contents of all materials tested have consistently run below 0.1% for 1999. Past Chinese samples, again, were significantly higher in the past. Today, traders are doing a better job of screening for nitrogen and sulfur and both of these values have fallen significantly in the Chinese material.

Alumina may or not be a problem depending on the particular alloying application. In one gray iron induction furnace shop, where melt temperatures were as low as 1400^{o}C, silicon recoveries were reduced with silicon carbide that was high in alumina compared to an equivalent grade of SiC with lower alumina. In ductile iron shops, where melt temperatures are higher, no difference between low and high alumina materials has been observed. Alumina is a strong refractory material and it may be possible that at lower melt temperatures it thickens the slag to the point that interfere with recoveries.

Again, high alumina problems are a Chinese situation. No domestic numbers were available for this paper, but Russian material was tested at 0.5% and South American at 0.2% alumina. It is assumed that Canadian and U.S. materials, with the abundant low alumina silica available, are at or below the South American levels. Chinese materials have been tested as high as 2.5% alumina. Further testing of new shipments is being conducted. It is likely that the alumina is an impurity from either the sand used or from the coal ash that is left in the burn. Since there are a significant amount of different Chinese producers, it is likely that the alumina contents vary significantly from region to region.

A critical factor when choosing a silicon carbide grain is cost. A 90% silicon carbide gives the melt operator about 63% available silicon. If we compare the price of 90% silicon carbide with the November 1, 1999 price of 75% ferrosilicon at 36.65 cents per pound of silicon, then a price of $462.00 a short ton would be an equivalent silicon price. This is not including the benefit of the carbon. Chinese materials are currently selling close to this price in the market, making them a competitive decision. Domestic, Russian, and South American products tend to be higher than this, making a buying decision dependent on the other advantages of silicon carbide besides silicon price.

Cupola Foundries
In cupola foundries, SiC grain cannot be readily used due to its particle size. A significant amount of the grain would readily leave the system via the dust collector.

Briquettes are made on a block or paver machine in a variety of SiC and C levels. A picture of a paver machine used to make briquettes can be seen in **figure 1.** Lower levels of SiC, such as 36 to 40%, are used in conjunction with high carbon contents to lower the coke rate of the cupola

Figure 1: A paver machine that is used to briquette alloys for the foundry industry.

furnace. Higher SiC levels, 65 to 70%, are made as more or less straight silicon replacements.

Briquettes are made in either slab or bulk form. Slabs are made to a given weight and usually manually thrown into the charge bucket. Since their weights and chemistries are known, a given number of slabs will be put into the charge to give the desired percentage of silicon.

Bulk briquettes are designed to flow through bulk handling systems that weigh a certain amount for each charge. Again, since the chemistry is known, a given weight is selected to obtain the desired silicon content. The briquettes are designed to handle well and fines are kept to a minimum to prevent plugging of gas flow in the furnace.

Figure 2: Typical Chemistries for SiC Briquettes

	Low SiC	**High SiC**
% SiC	36	65
% Total C	40	29
% Free C	29	10
Moisture, %:	7	4

Other alloys, such as manganese, can also be added to the briquette mix. Typical chemistries for two common industry standards can be seen in **figure 2**.

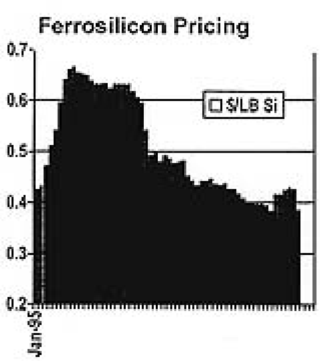


Figure 3: Ferrosilicon pricing since 1995. Source: Ryan's Notes

The Market

Despite its operational advantages, silicon carbide is not the only available silicon source to the melt operator and cost of alternate materials must be considered in the SiC mix. The most common alternate sources of silicon to the melt operator is ferrosilicon, either 50 or 75% available silicon. Price for these products have fallen in recent years as can be seen in **figure 3**.

Other sources of silicon available include silicon dross, silicon briquettes, silvery pig, pig iron, and foundry scrap. Silicon dross is a by-product of the silicon industry and contains trapped "metallic" silicon inside of a silica slag. Silicon briquettes are often made with silicon units too fine to be added directly to the cupola and include sources such as ferrosilicon fines, silicon dross fines, and silicon carbide.

Because of the perceived advantages and a competitive pricing situation with SiC, its use has increased significantly over the last 10 years as an alloy addition. For 1998, the estimated total market for SiC in the United States was 300,000 metric tons, with approximately 200,000 metric tons being earmarked as alloy additions.

As pollution control requirements have increased in North America, the number of active producers has fallen from 8 to 2 over the last 10 years. In 1998, the last year the USGS reported domestic production, output in the U.S. was estimated at 68,000 tons. Thus, the increase in SiC as an alloy addition has largely been

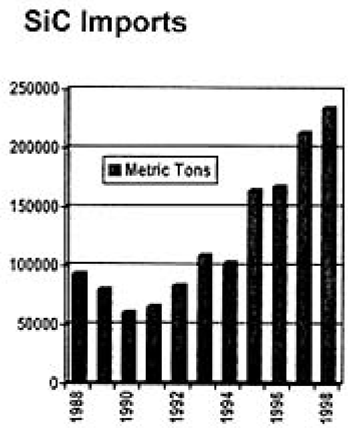


Figure 4: SiC imports from 1988
Source: USGS

covered by imports.

Figure 4 shows total SiC crude imports as reported by the USGS. The four largest importing countries over the last 5 years have been China, Canada, Brazil, and Russia. Chinese imports have dwarfed those of other countries as can be seen in the comparison with Canadian imports in **figure 5**. Ten years ago, imports from Canada made up the majority of the imported material. Today, approximately 80% of imported material is from China.

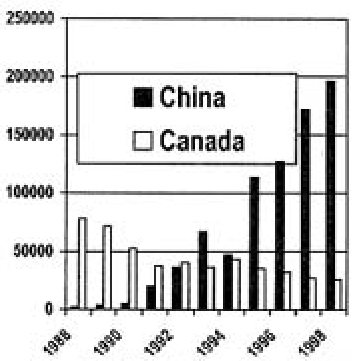


Figure 5: SiC imports from Canada and China since 1988. Source: USGS

As silicon carbide has become more important as an alloy addition, Ryan's Notes started tracking the price of crude Chinese 88% material. This started in March of 1998. This price at first dropped steadily. In February 1999, the Chinese government imposed a $50 per ton tax on silicon carbide. Looking at **figure 6**, this started to affect the price of material reaching the shore of the U.S. in July. Shipments between July and October, according to the USGS, were very low. Shipments started to pick up in November and some softening of the price was observed. It is expected that some continued softening from current pricing would continue as competitive materials, such as ferrosilicon, are also dropping in price.

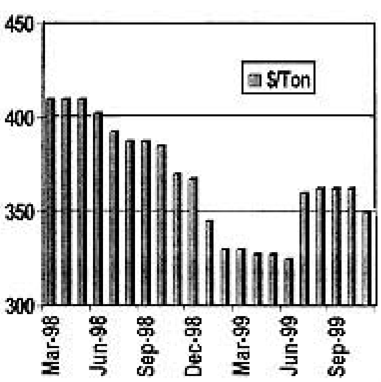


Figure 6: Silicon Carbide Pricing since March, 1998. Source: Ryan's Notes

Conclusions

Silicon Carbide is and will continue to be an important commodity for the abrasives, refractory, and ferrous-metals industry. As an alloy addition, SiC has increased in importance substantially over the last 10 years. A lot of this increase is due to low cost imports from China. Recent increases in SiC price are under pressure due to falling prices of some competitive materials such as ferrosilicon. Thus, it is expected that crude silicon carbide pricing will be stable or fall slightly through 2000.

Thermal Analysis Testing for Acceptable Mg Content

(A Practical Low Cost Method)

by Jack Oakey
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Introduction
In today's world, businesses are being driven by their customers, owners, and competitors to increase production and decrease operating costs while producing products of ever-increasing quality. The producer of ductile iron castings is no exception to these pressures. In the midst of these demands from all directions, the ductile iron foundry operator must be particularly concerned that the proper degree of nodularity is achieved for each and every part that is produced and sent out to a customer without sacrificing production rate and increasing the costs of the operation.

All of you are familiar with the potential dire and catastrophic consequences that the production of improperly processed products can have on any particular foundry.

First off, there is the question of are you even aware of having produced bad material. If you are aware of it, there is always the uncertainty that all of the defective parts have been properly identified and segregated. Of course, if any of the bad material reaches the marketplace, there are always the potential problems of costly recalls, or far worse, liability lawsuits that could possibly put the company out of business.

Commonly Used Methods for Nodularity Testing
Currently, the most common methods used by ductile iron foundries for the determination of nodularity are microexamination and emission spectrometry. Both of these methods leave something to be desired in everyday foundry use.

Microexamination
The problems of using microexamination to determine the degree of nodularity for cast parts are many. First off, the technique is very slow and only provides information after the fact, well after the metal has been cast. Because of the delay in obtaining results, bad castings can get into the downstream system and this triggers a "scramble" to segregate parts. This occurrence results in loss of production and potential increased scrap rates. Further, the microexamination technique can be greatly influenced by the subjectivity of the individual performing the examination. It is only reliable when the personnel are well trained and consistently utilize very good technique. The learning curve is very high and can be quite costly to perfect.

Spectrometry
The use of an emission spectrometer provides compositional information faster than the microexamination method. However, spectrometry still requires sample preparation time and the results also become available after the fact or production delays are taken while awaiting the results. In addition, the equipment required is quite expensive and must be properly maintained.

Low Cost Thermal Analysis Technique
The remainder of the presentation will focus on a patented low cost thermal analysis technique that is being marketed by L&N Metallurgical Products. This system can tell the operator if the magnesium content of the treated iron is above an established threshold level. The system consists of specially prepared disposable thermal analysis cups, referred to as MgCUPs, and an instrument, MgLAB, that provides the pass-fail information through analysis of the cooling curves.

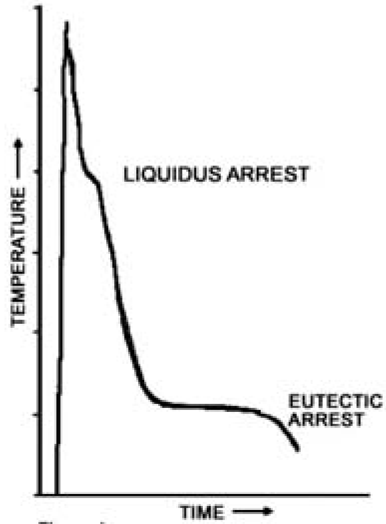

Figure 1

How System Works

It is known that the use of tellurium in a thermal analysis cup provides a carbidic solidification structure and an analysis of the resulting cooling curve can be used to determine the carbon and silicon composition of the metal. An example of the cooling curve for this situation is shown in Figure 1. However, in the presence of magnesium, tellurium can not prevent the iron from solidifying with a graphitic eutectic structure. The cooling curve for this situation is shown in Figure 2. Further, if sufficient sulfur is present in the cup to neutralize completely any magnesium that may be present in the iron, the tellurium again becomes effective in achieving carbidic eutectic solidification. With the magnesium neutralized, the metal again acts as if no magnesium were present and the resulting cooling curve is as shown in Figure1.

The MgCUP/MgLAB system utilizes the above-described changes in cooling curve behavior to provide PASS/FAIL information in real time to the operator on the foundry floor.

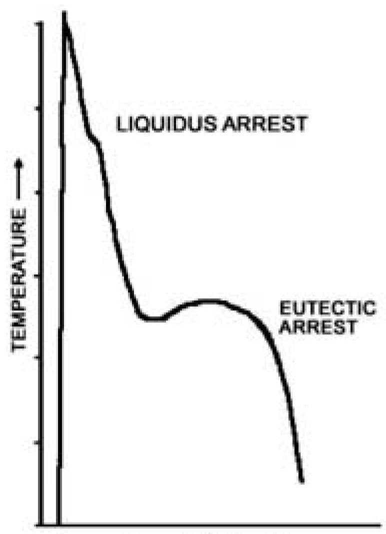

Figure 2

The process starts with a specially prepared thermal analysis cup that contains not only tellurium, but a specific amount of sulfur that is consistent with the lowest acceptable, or threshold, level of magnesium for the particular foundry under consideration. Following the addition of magnesium to the iron, a MgCUP is poured and the MgLAB instrument analyzes the resulting cooling curve to determine if sufficient magnesium is present. It is recommended that the temperature of the iron that is poured into the MgCUP be greater than 2390^{o}F so that good cooling conditions are obtained in the cup before any measurements are made.

The MgLAB analyzes the cooling progress of the poured sample and looks at the time it takes for the sample to cool from one predetermined temperature level to another temperature level. When the temperature falls to 2138^{o}F the timer is activated. When

o

the temperature reaches 2075 F the timer is halted and the elapsed time is evaluated. A relatively long cooling time, greater than a minute, indicates graphitic eutectic solidification. A relatively short cooling time, less than a minute, indicates either carbidic eutectic solidification or a mixture of carbidic and graphitic eutectic solidification that produces a "mottled" structure.

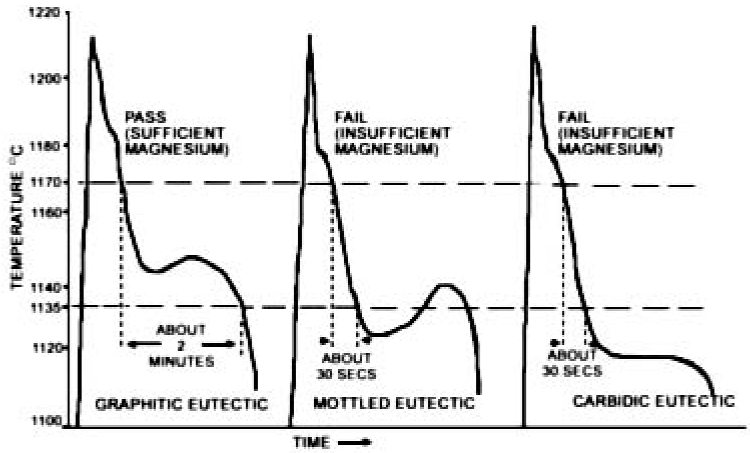

Figure 3

Figure 3 illustrates the various curves that can result with the use of the MgCUP. The first, 3a, shows a graphitic eutectic and indicates that there is sufficient magnesium present, over and above that required to react with the sulfur addition. As can be seen, the time elapsed as the sample cools through the two temperatures of interest is greater than one minute. The result indicated by the MgLAB instrument is PASS. Figure 3b illustrates the case of a "mottled" structure and figure 3c is an example of a carbidic structure. The elapsed time between the two temperatures of interest for both of these cases is less than one minute. For both of these situations there is insufficient magnesium in the iron to meet the threshold level and the MgLAB would indicate FAIL.

The MgLAB instrument can also be connected to remote devices to show results to the operating floor and to computers for data storage and archiving purposes. A printer can be hooked up to the MgLab for a hard copy record of test results.

Through experience, different foundries have found that different levels of magnesium are required as the target threshold levels required to achieve satisfactory nodularity. This thermal analysis system can be readily adapted to accommodate various threshold levels of magnesium through adjustment of the amount of sulfur that is incorporated into each thermal analysis MgCUP. Hence, the system can be tailored for each individual foundry.

Advantages of Thermal Analysis System

By using the MgCUP/MgLAB system on a routine everyday basis, the foundry operator can bring about a number of advantages to the operation.

The test can be performed very quickly and requires only two minutes from start of test to the PASS/FAIL indication from the MgLAB instrument. As a result, no bad iron castings should get into the system. If the results from the MgCUP indicate FAIL, the iron can be pigged immediately or, time permitting, further magnesium additions can be made. Either way, improperly treated material will not be cast. There will be no stoppages of production and defective parts will not have to be retrieved from the downstream system.

Test subjectivity and the human element is essentially eliminated from the test results. Further, no operator training is needed to obtain the results. Pouring a MgCUP is no different than pouring a standard thermal analysis cup. The MgLAB instrument then takes over, interprets the information and provides the PASS/FAIL results without human interpretation.

Summary

To summarize, the L&N Metallurgical Products MgCUP/MgLAB system offers a low cost, rapid method to determine if sufficient magnesium has been added to the base metal.

The system requires no training on the part of the operator and human intervention or interpretation does not enter into the process.

The utilization of the system can lead to a number of advantages for the foundry operator that relate to quality of product, yield, and production rate.

However, the system may not be applicable or cost effective for all foundries. Current practices and experiences, as well as past history, may indicate that this thermal analysis approach is not of interest or cost beneficial for your foundry.

Rapid Determination of Magnesium in Ductile Iron

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Abstract
There are many different treatment methods to produce ductile iron. All of them involve the introduction of magnesium in some form; either alone or in combination with cerium or other rare earth metals. Successful production of high quality ductile iron depends on the successful control of magnesium. Operators are constantly on the vigil in controlling and maintaining sufficient amount of magnesium in the iron to promote satisfactory nodularization.

In a batch process of production such as in ladle, sandwich or tundish operation or in a semi-continuous operation of treatment-pressure pour combination, it is difficult to maintain the level of magnesium. It is also equally difficult to know the exact percent of magnesium in the melt before pouring. A major concern expressed frequently by the ductile iron producers is, is there a way to rapidly and accurately test and analyze the final metal not only to ensure the success of the magnesium treatment but also to know the exact percentage of magnesium to make up adjustments to charge additions? One possible way is to apply the principle of thermal analysis to analyze final iron. BCIRA applied this principle as far as to accept or reject a batch of metal, with 0.04%Mg as the reference. Present authors have extended the applicability of thermal analysis to predict exact percentage of magnesium in the final iron. The analysis, made in a tellurium/sulfur cup is displayed in less than three minutes of pouring.

Introduction
Ductile iron also known by the names of spheroidal graphite and nodular iron is made by treating the liquid cast iron with special "spheroidising" elements to promote the precipitation of graphite in the form of spheroids rather than as interconnected flakes. Alkaline earth metals that include magnesium and calcium and the rare earth metal such as cerium, lanthanum, and yttrium all have been proved to be the special elements.

In most American foundries, treatment with magnesium (Mg) is used in the production of ductile iron. Magnesium is a very highly reactive metal with a low vapor pressure and this combination results in a considerable loss of the element during treatment. In practice, excess amount of magnesium is added to the base metal to retain a certain level of residual magnesium in the treated metal. Residual magnesium level which produces completely spheroidal graphite is observed to be between 0.02-0.06%. A very low magnesium can result in insufficient spheroidisation and a very high magnesium can result in porosity and carbides. Under both conditions, the produced castings will be of inferior quality. The critical "low-high" window for magnesium, though universally accepted as 0.02-0.06%, has been trimmed and narrowed by individual foundries to suit their production and quality standards.

It is not an exaggeration when we say that the addition and control of magnesium is the single most important step in the production of ductile iron, and the production of quality castings is determined by how well a foundry can precisely control the level of magnesium in their melt. This becomes doubly crucial when the foundry runs a Converter treated iron with a Presspour system and a DISA set up.


Photo 1

Fisher converter Presspour combination
In this setup, the base metal is treated in a Fisher converter (Photo 1) and then transferred to the presspour pouring furnace before pouring the inoculated metal into the molds (Photo 2) automatically. This operation is ideally suited for a high production foundry that can handle a large tonnage of hot metal every hour.

Fisher Converter:
Here the treatment involves the use of pure magnesium in a closed chamber. In the chamber very violent reaction takes place. A high percentage of

Photo 2

magnesium recovery is achieved in this process. Reaction only takes a few minutes but the preparation of the chamber takes about 10-15 minutes with the possibility of only 3-5 taps per hour. Converter treatment produces a cleaner iron with less slag, permits the use of high silicon returns in the charge material, and tolerates a high sulfur base iron.

It is not easy to predict the recovery of magnesium in the converter process. Many factors influence this; the extent of reaction; the consistency of operation, reaction of magnesium whether complete or insufficient, plugging of the holes in the chamber plate, over tapping of metal, build up of slag inside the reactor, improper amount of added magnesium or any other inadvertent operator negligence.

Even though the time of reaction is monitored as a precautionary check, it is not always possible to guess the success of the operation or to have a knowledge of the magnesium in the liquid metal. It is important to know this for two reasons:

1. **how much magnesium is going into the presspour pouring furnace**
2. **how much pure magnesium should be added to the converter in the next step so as to maintain an optimum level in the pouring furnace**

Presspour Pouring Furnace:
The function of the pouring furnace is to act as a reservoir of ready source of treated iron. In addition to this, the furnace helps to maintain the temperature of iron. Both magnesium and temperature can be closely controlled here. The treated iron from the converter is immediately transferred to the furnace fill spout in batches of 2-4 tons, depending on the capacity of the converter. Therefore, there is a close control in the cycle of metal flow right from the time the base metal is dispatched to the converter for the treatment to its storage in the holding furnace and drain through the pouring spout to the casting molds. Photo 2 shows the entrance of the metal in the fill spout into the furnace and the flow through the pour spout.

Two major problems are encountered here:

a. **magnesium fading: continuous loss of magnesium with time due to the reaction with oxidizing atmosphere, other elements, increase in temperature.**
b. **resulfurisation: if the converter slag enters the metal and remains there, the slag mainly, magnesium sulfide (Mg_2S), will react with oxygen to form magnesium oxide (MgO), and sulfur (S). The released sulfur will enter the melt, thus increasing the S level. An increase in S in the melt will reduce the amount of magnesium available for spheroidisation.**

As a result of these two factors, the magnesium percentage in the furnace continuously fluctuates, more so when the melt is held for a considerable length of time. Therefore, it is very difficult to even guess the percentage of magnesium in the holding furnace. For a good control of magnesium, a knowledge of %Mg in the furnace is important for the following two reasons:

1. **how much magnesium is in the pouring furnace**
2. **how much pure magnesium should be added to the converter in the next tap so as to maintain an optimum level in the furnace**

Pressure Pouring Spout:
The metal in the furnace is pressurized to fill the pouring basin which has the stopper rod auto pouring mechanism. The metal in the basin is inoculated by wire treatment process and is further aided by instream inoculation during filling of the molds. Precise quantity of treated and inoculated metal is delivered by the automatic pouring system into the continuous array of molds generated. Level of magnesium at the pouring basin near the pouring spout depends on

1. **how much magnesium is transferred from the converter to the furnace each tap**
2. **how much magnesium is already present in the pouring furnace**
3. **how long the metal has been held in the pouring furnace**
4. **temperature of the pouring furnace**

5. **oxidation and resulfurisation of the melt**

The Problem:
So the metal in the pouring basin ready to be cast is the latest point at which it is essential to maintain magnesium within the limits for acceptable nodularity. Magnesium content in the pouring basin is a cumulative effect of the previous two operations, what happens in the converter and holding furnace. Magnesium content decreases in an unpredictable way with any delay in any one of the processing steps. Given the fluctuation of magnesium every minute, it is absolutely essential to actually know the exact percentage of magnesium at this point of production. This is important because

1. **if magnesium is within allowable range, it gives a go ahead confidence to continue to pour the metal without risking the production of scrap castings**
2. **if not, it gives a warning to treat the converter with a super tap or higher amount of magnesium to make up for the deficiency.**

To know the exact percentage of magnesium, the sample has to be analyzed spectrographically. It takes time. Any time spent in waiting for the analysis result will cause

a. **a further loss of magnesium**
b. **an increase in down time, loss in production and loss in revenue**

The decision to pour or treat has to be made on the shop floor, rather quickly on the spot, otherwise the production will be delayed, with a net loss in revenue.

So in a high production foundry there is a grave need for a quick control tool which would inform the operator about the quality of the molten metal before the metal is poured. There is a considerable cost savings if a procedure is established where by quick analysis of residual magnesium is made available. Is there a way?

Magnesium Analysis:
One direct way to estimate the percent magnesium is spectrometer analysis of the sample cast in a special mold. The poured sample has to be transported from the pouring basin to the location of the spectrometer, where it is ground and analyzed spectrographically for the elements. There is an understandable delay in obtaining the results for a feed back. In a busy foundry this may take any where from 15-30 minutes or more.

An indirect way to insure that there is enough magnesium to cause spheroidisation is metallographic examination of the cooled sample poured from the metal to be cast. This is a widely used method for checking the graphite structure, as spectrometer instrument is expensive for small foundries to afford. However, this method like spectometer is equally time consuming and labor intensive. Besides, the metallographic method only gives the go ahead for the poured sample, but does not indicate where the exactly the magnesium is in the allowable window. Without this knowledge the operator still cannot make a decision as to how to adjust his charge material for treatment to continue maintaining the required magnesium.

Metal cannot be held for the results from spectrometer or metallographic examination to be relayed as this holding will lead to further magnesium loss.

BCIRA in collaboration with L&N had developed a system called MgLab that would indicate whether the melt has sufficient magnesium of 0.04% (or (0.35%). The prediction is based on the cooling curve characteristics obtained in a specially formulated cup containing controlled quantity of sulfur (to combine with magnesium) and tellurium (to make the iron solidify as white iron after removing magnesium as MgS). The results are displayed as Pass/Fail message within three minutes of pouring the sample. A fail sample can have a magnesium of any where from 0 to 0.04 percentage (or 0 to 0.035%) and a Pass sample can have magnesium anywhere above 0.04% (or 0.035%).

This is a very good, quick and easy alternate method. But the most important question in the production floor, particularly when you have the metal in the holding furnace with a constant fluctuation of magnesium, is not just a Pass or a Fail, but what is the exact amount of magnesium in the melt. The exact amount is important because the entire operation depends on the control of magnesium and this information is needed to make decisions to adjust the additions at the starting point of the cycle. This is a vicious circle where one has to be extremely vigilant and make decisions readily to keep up the production of quality castings.

Drive towards a method of rapid determination of magnesium
The converter-presspour system started operation in the beginning of 1997. At that time for magnesium control an old MgLab was used to check the Pass/Fail condition and a procedure was set as to how to react to the message. Many times this wasn’t enough for the operators. A Fail sample could be anywhere from 0.02 to 0.042 and still they had to wait for the spectrometer analysis. For casting in the molds it is okay to go with the metallographic examination; all it implies is that the particular metal in the pouring basin at that instant is good. However, to sustain the magnesium in the holding furnace, they needed to know the precise amount of it in the final metal, so they can adjust their treatment charge.

Having to play with their gut instinct to keep the magnesium under control, this was raised as the foremost important issue in every meeting. So it was decided to devote a person to look into the methods of predicting or analyzing magnesium in the final metal at the pouring station. After a quick study it was decided to explore the same technique of "cooling curve" analysis, which is also the basis of MgLab. Same specially formulated Te/S coated 0.04 commercially available cup was considered. The MgLab unit was first generation unit about twenty years old and had no display of cooling curve or any parameters.

Experiments were run in parallel to MgLab. Molten metal from the pouring basin was poured into the cup and data collected by means of a data acquisition system. Extensive testing on a wide range of compositions was made. Numerous cooling curves were analyzed for special features. Critical parameters were found which were very sensitive to magnesium variation. These parameters reflect the way in which sulfur and tellurium present in the cup affect the nature of solidification of the iron. Based on these parameters, a set up has been established in the foundry, which analyses the cooling curves, measures the parameters and displays the percent magnesium on the screen. The analysis is made within three minutes of pouring.

Table 1 shows the data collected randomly over a period of three months during production (only 25 points listed).

Table 1: Comparison of Magnesium Values

%Magnesium Comparison: ProcessLab vs. Spectrometer		
Sample #	**ProcessLab**	**Spectrometer**
1	0.043	0.046
2	0.043	0.045
3	0.036	0.039
4	0.042	0.041
5	0.043	0.043
6	0.034	0.036
7	0.039	0.038
8	0.036	0.032
9	0.036	0.034
10	0.033	0.034
11	0.038	0.035
12	0.047	0.043
13	0.043	0.044
14	0.042	0.047
15	0.029	0.033
16	0.036	0.037
17	0.043	0.04
18	0.036	0.037
19	0.033	0.035
20	0.043	0.041
21	0.043	0.049
22	0.043	0.048
23	0.042	0.045
24	0.042	0.05
25	0.039	0.038
26	0.034	0.036
27	0.043	0.044

The predictions are compared against the magnesium analysis by spectrometer. The data shows the results are in close agreement, accurate and reliable particularly in our critical range of 0.025-0.048%. Table 2 shows that most of the results were within 0.004 points from the spectrometer values.

Table 2: Summary of Data Analysis	
Number of data points: 115	
Cell size: 0.001	
Delta MG = % Magnesium (Processlab-Spectrometer)	
Delta Mg	**No. of Occurrences**
-0.014	1
-0.012	2
-0.011	1
-0.008	1
-0.007	2
-0.006	3
-0.005	5
-0.004	7
-0.003	13
-0.002	12
-0.001	12
0	16
0.001	11
0.002	6
0.003	5
0.004	8
0.005	5
0.006	3
0.007	2

Comparisons were also made with magnesium analyzed by wet chemical methods and magnesium analyzed by an external lab which is routinely done in the foundry. In all cases the magnesium prediction has been very satisfactory.

The predictions were possible because of the rigid control in chemistry of other elements, manganese and sulfur. Manganese and sulfur can influence the prediction. But in a converter process where there is a natural desulfurisation occurs, sulfur is reduced to a minimum value. Sulfur hardly exceed 0.007% during production, except during start up. Manganese is controlled by the choice of a good quality steel as a charge make up in the base melting. Other tramp elements Mo, B, Sn, Ni are controlled within limits. From the data collected over a period of three months, the following variation in chemistry in the final iron was recorded: C=3.60-3.81, Si=2.55-2.78, Mn=0.262-0.282, Cr=0.027-0.031, Sn=0.007-0.009, Ni=0.024-0.026.

Other elements that fluctuate a little bit are carbon and silicon. Silicon variation mainly comes from the inoculation treatment, which can vary from one casting geometry to another. The combined effect of carbon and silicon as CE may be one restricting factor in the prediction. It is important to have a eutectic or hyper eutectic alloy composition and the prediction. It is important to have a eutectic or hyper eutectic alloy composition and the prediction has been seen to be good for the CE of 4.45 or higher.

Total vs. Active Magnesium
The magnesium analysis given by spectrometer method is total magnesium whereas the magnesium analysis given by cooling curve method is active magnesium.

Magnesium is a very powerful deoxidizer and a desulfuriser. Oxygen combines with magnesium to form magnesium oxide and complex silicates and sulfur in the metal combines with magnesium to form magnesium sulfide. Analysis given by spectrometer is referred to as the **total** magnesium which includes the dissolved magnesium and magnesium bound as compounds present in the sample. Analysis given by spectrometer does not differentiate how magnesium is present in the sample.

Total Mg = Mg dissolved + Mg compounds (oxide, sulfide, silicate)

Magnesium present as compounds will reduce the available quantity of magnesium to promote spheroidisation. Therefore actual amount of magnesium that is truly contributing to the formation of spheroids is that which is in excess of that which combines with sulfur and oxygen. This excess magnesium is referred as the **active** or **free magnesium**

Active Mg = Total Mg – Mg compounds (oxide, sulfide, silicate)

It is the active magnesium that controls the structure of graphite. Analysis of active magnesium is very difficult compared to the analysis of total magnesium by spectrometer.

Correlation of total magnesium to active magnesium can be made, such as the one in the present work, provided

a. **consistent melting practice is followed**
b. **oxygen content in the base iron and bound magnesium oxides are kept within a narrow range**
c. **sulfur content in the base iron and bound magnesium sulfide are controlled within a narrow range**


Photo 3

Further developments
In the last two years after the initial setup was made in the foundry, STAS Canada, has developed and built a compact thermal analysis unit to measure percent magnesium in iron. Figure shows the photo of the ProcessLab (Photo 3) unit for magnesium. The unit is simple, automatic and has standard features of storing and exporting results. In addition to giving magnesium within three minutes, the unit also gives a Go/noGo message (Photo 4) within two minutes of pouring. Photo shows the Go message (or a noGo message as the case may be) and the percent of magnesium 0.047 in this case. The number 2 seen on the display indicates that the results are from input or channel No. 2.

Photo 4

Conclusion
The principle of cooling curve analysis has been extended to predict percent magnesium in the treated iron to facilitate swift decision making on the floor. The prediction is fast, reliable and accurate and has been helping the foundry for the past two years.

Experience With Recarburizers

More Experience With Graphitic and Non-Graphitic Recarburizers in Ductile Iron Production

by William A. Henning, V.P. Technology
Miller and Company LLC; Rosemont, IL

Abstract
As follow-up to a similar comparison of recarburizing materials reported on in 1999 AFS Transactions, a second, more extensive trial has been completed at a commercial ductile iron foundry. The results from 58 production days have been accumulated and are reported on in the paper, including carbon recovery, complete metallographic evaluation, and effects on mechanical properties. Over 1200 ductile iron heats were accomplished during this time frame, and the results mirror those reported on in the earlier paper. Once again there was no advantage seen in the use of a crystalline recarburizer, as compared to the use of a low sulfur, non-crystalline petroleum coke.

Introduction
When reviewing the literature on the subject of recarburizers to be used for ductile iron production, one is hard pressed to find any recommendation except that to use crystalline graphite, such as crushed electrode scrap. This is very logical, since that was the only type of material totally suitable for quite some time. However, about 12 years ago, a low sulfur, non-crystalline petroleum coke became available and it had an immediate impact on the marketplace, primarily due to the favorable economics associated with this new product. Some controversy evolved as to the ability of this material to produce high quality grades of ductile iron, in spite of the fact that dozens of foundries had been using it successfully for a period of years. With the cooperation of a high production ductile iron foundry, data from a five-day production test was reported on in a previous paper published in the 1999 AFS Transactions. The conclusion of that paper was that equivalent, or even slightly superior results were produced when the foundry was utilizing the non-crystalline product, as compared to irons produced when using a crystalline graphite product. That conclusion was based almost entirely on metallographic evaluations. Several months later, when another foundry became interested in the subject and wanted to complete a similar, but considerably longer trial, to include carbon recovery and mechanical properties comparisons, the wheels were set in motion to begin the trial and start collecting data, all of which is summarized in this paper.

Also included in this most recent report is similar data generated with the use of a partially graphitized, refined petroleum coke, which will be referred to hereafter as "PG". Data was gathered from 58 production days, which included 1275 ductile iron treatments. The data is divided into four chronological segments; initially, an 8 day production run using "PG", followed by 16 days with graphitic material, then 18 days using non-graphitic recarburizer, and followed lastly by a second 16 days use of graphitic material. Carbon recovery, microstructural results, effects on mechanical properties and base chill wedges will all be reported on.

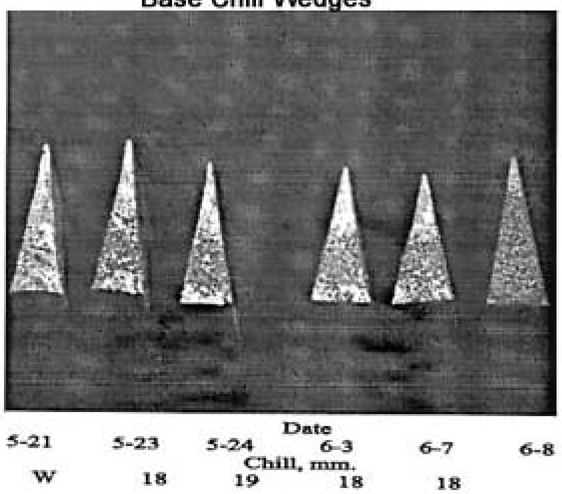
Discussion
The foundry in which the testing was completed utilizes as primary melters, two 5.5 ton medium frequency coreless induction furnaces. The base charge typically contains about 50% local return scrap, 43% steel scrap, 5% low phosphorous pig iron, with the balance being recarburizer plus small amounts of 90% SiC grain and 75% ferrosilicon for trim purposes. The base metal is duplexed through a 25 ton vertical channel furnace. Nominal chemistry at this point is 3.8% carbon, 1.6% silicon, <0.30% manganese and <0.10% copper. Base sulfur levels will be discussed later in this report. Nodulization is in a 1500 lb. Tundish ladle, with a 1.6% addition of a 6% magnesium, 0.3% cerium alloy. Post-inoculation is accomplished by using 0.6% calcium bearing 75% ferrosilicon, plus a small amount of barium containing alloy, added to the metal stream as the treated ductile iron is transferred to a 3500 lb. unheated, bottom stopper auto-pour that supplies metal to the single vertically parted molding machine in the plant. In spite of the fact that the castings produced here are quite small, varying from 0.4 – 15 lb. in weight, there is no mold or stream inoculation employed. Final silicon and magnesium levels vary between 2.65 – 1.80%, and 0.038 – 0.044%, respectively.

Carbon Recovery
With the medium frequency furnaces as melters, a chemistry sample is taken when the metal gets to temperature and prior to that entire heat being tapped and laundered directly to the holding furnace. Because the foundry keeps accurate records of the amounts of metallics in each furnace charge, it is thus very convenient to calculate carbon recovery for each 11,000 lb. furnace charge, which in fact was done for the entire 58 days of data collection. As can be seen in Table 1, the recovery numbers are unusually high, probably due to some error in the assumptions made about the carbon level of the various charge materials; however, in any case they are relative, since the same assumptions were used throughout the entire test period, and irregardless of the recarburizer in use at the time.

Table 1			
Carbon Recovery			
Recarburizer	**No. of Production Days**	**No. of Heats**	**% Carbon Recovery**
"PG"	8	164	98.82
Graphitic	16	351	98.70
Non-graphitic	18	400	97.87
Graphitic	16	360	95.26

Base Chill Wedges
This foundry does not normally pour chill wedges, but since some cores were available, it was decided to pour a few random samples on different days for informational purposes. The wedge dimensions are 1-3/8" high, by ½" wide at the base. Results are shown in **Figure 1**.

Figure 1
"Base Chill Wedges"



One can draw his own conclusions as to these results. It would not be appropriate to present an average chill depth, as the author's opinion is that this would be misleading. First of all, not many samples were poured. Second, the wedge poured on June 8 had so much less chill that it appears possible it received "inoculation" from a random particle of graphite. The simplest conclusion is that wedges poured with graphitic recarburizer has lower chill values than those poured with non-graphitic recarburizers, as would be expected. In any case, the chill wedge values had no relevance to the final irons produced, as will be shown by later data.

Metallographic Results
During the entire 58 days of testing, not one suspect nodularity heat was produced. Nodularity checks are taken from a coupon cast into the mold, with the sample taken to correlate to the last metal from each tundish ladle treatment. Due to the light nature of the castings being produced, a casting is removed from the molding line once each hour to check for carbides. If the amount of carbide found is in excess of that permissible for the particular job being run, those castings are contained for further examination. This foundry had a history of carbide problems, which at least partially prompted the testing of the alternative recarburizers, as the incumbent product had been "PG".

The summary of the 58 days of hourly carbide checks is shown in Table 2.

Table 2			
Hourly Carbide Checks			
Recarburizer	**No. of Production Days**	**No. of Heats**	**% of Samples Showing Carbides**
"PG"	8	164	17.0
Graphitic	16	351	3.1
Non-graphitic	18	400	1.5
Graphitic	16	360	2.2
		1275	

"PG" production days were from a period of time thought to be representative of normal production, and comparable to the successive test days of the other materials, but actually took place a couple of months prior to the balance of the testing. To be fair, the data in Table 2 does not tell the whole story as related to the propensity for carbides in this foundry. There is certainly nothing wrong with the "PG" product. Furnace sulfur levels when using "PG" averaged 0.0042%, normal at that time, and this foundry was encountering a lot of carbides due to the low base sulfur of the iron being melted, as has been experienced at other foundries, as well. It was this scenario that led to the testing of the alternative recarburizers, both of which were slightly higher in sulfur content that "PG". Average base sulfur levels when using the non-graphitic recarburizer was 0.0106%, and nearly identical with the graphitic material. As soon as the base sulfur level increased, the frequency of positive carbide checks was reduced dramatically. If anything, the sulfur level of "PG" was simply too low.

Although there was no indication of differences in the ductile irons produced with graphitic or non-graphitic recarburizers, it had been decided prior to beginning of the trial to submit random samples for image analysis. The structures were analyzed on a Clemex Vision 1024, utilizing 200x magnification with a filter that removed particles smaller than 3.9µm square. Sixteen fields were evaluated for a total area of 4.1mm^2. The areas examined were in the center of the samples, however, when porosity was present, it was avoided by circumscribing the porous region. Criteria for nodularity was sphericity of $\geq$0.60 and aspect ration of equal to or less than 2:1 – if either condition was not met, the program would treat the particle as degenerate graphite. All data is shown in Table 3.

Table 3

Image Analysis Results

Recarburizer	**Date**	**Heat No.**	**% Nodularity**	**Nodule Count per mm^2**
Graphitic	4-2	28	92	388
	4-22	5	96	386
	4-22	9	94	391
	4-23	43	97	464
	4-23	47	95	385
	4-30	3	96	508
	4-30	7	95	424
Non-Graphitic	5-10	2	90	319
	5-10	3	94	324
	5-10	4	95	351
	5-10	7	95	376
	5-10	8	95	359
	5-20	2	96	569
	5-20	5	96	464
	5-20	6	94	350
	5-20	7	97	572
	5-20	14	97	446
	5-20	20	97	562
	5-22	18	94	369
	5-22	23	91	352
	5-22	25	95	490
Graphitic	6-1	23	94	401
	6-3	30	95	418
	6-3	38	96	444
	6-5	28	95	478
	6-5	31	95	470
	6-7	18	95	429
	6-7	30	96	481
Averages			**% Nodularity**	**Nodules per mm^2**
Non-graphitic			94.7	422
Graphitic			95.0	436

Although the nodularity and nodule counts with graphitic material were slightly higher, there are no significant differences. A closer examination of the data will reveal that the nodule counts for May 10 were considerably lower than any of the other days for which samples were submitted. During the time frame when these samples were being poured, magnesium residuals were running 0.043%-0.047%, considerably higher than for other periods during which samples were taken. It is well known that high magnesium residuals will adversely affect nodule counts. If one would ignore May 10 samples, the average nodule count with non-graphitic recarburizer rises to 464, now higher than with graphitic material. Like it has been said many times before, if you let somebody massage the data long enough, he can get it to say anything he wants. The only point here is that the attempt to collect "random" samples fell short, with 6 of the 14 samples collected during the non-crystalline period coming from one day, and from a short period of time when magnesium residuals were higher than normal. It must be kept in mind that the data represents only 29 samples out of 1275 heats poured during the test, and the absolute value of the results is thus questionable. It was simply cost-prohibitive to submit more samples to the commercial laboratory for further image analysis work.

Effect on Mechanical Properties
According to the foundry quality program, it is required to pour a test bar daily. For certain customers, a test bar is required for each production run. Thus, there are typically anywhere from one to four bars poured daily. Both 65-45-12 and higher tensile grades are poured in the foundry, but only the data form the 65-45-12 iron was considered for purpose of this report. Mechanical property data collected is shown in Table 4.

Table 4

Effect on Mechanical Properties

Product	"PG"	Graphite	Non-Graphitic	Graphite
No. of Prod. Days	8	16	18	16
No. of Test Bars	10	25	25	19
Avg. Tensile, psi	72810	70396	70150	72605
σ	4725	3205	2348	3107
Ave. Yield, psi	48320	49167	48610	48858
σ	2630	2294	1533	1770
% Elong.	17.75	17.75	18.82	18.91
σ	1.9	3.89	2.29	1.84
BHN	174.4	162.4	161.0	168.3
σ	22.3	5.70	6.87	8.11

Once again, there is little to choose from between the graphitic and non-graphitic recarburized irons. Note the standard deviations associated with all the properties of the irons produced with "PG" recarburizer. The easy conclusion is that this is an inferior product, but such is not the case. The reason for the greater variability of these irons again rests with the very low sulfur contents of those base irons and resultant carbides that occurred on a very frequent basis.

Conclusions

1. Graphitic and non-graphitic recarburizers both produced irons with less carbides and reduced property variability, as compared to when a partially graphitized refined petroleum coke was in use. The main reason for this was in the different base iron sulfur levels.
2. No significant differences could be seen in metallographic or mechanical property results, whether a graphitic, or non-graphitic recarburizer was in use.
3. Carbon recoveries of either type of product are comparable. In fact, over the 50 production days studied, there was a slight advantage to use of the non-graphitic product.
4. Based on limited information, there was no relevance between base wedge chills and final iron characteristics.
5. There results confirm the findings reported in an earlier paper on the same subject published in the 1999 AFS Transactions.

Acknowledgement
Many thanks to Fred Fudge for volunteering to wade through all of the furnace charge data and calculate the carbon recoveries.

References
W.A. Henning "Comparing Crystalline and Non-Crystalline Recarburizers in Ductile Iron Production", Presented at the 1999 Casting Congress and to be published in the 1999 AFS Transactions.

FEF College Industry Conference

Drake Hotel, Chicago – November 4-6, 1999

Three hundred fourteen industry and university people attended this year's conference, along with 131 student delegates representing each of FEF's 30 schools, for a total of 445 people. This unique conference brought together top industry executives, FEF Board Members, Key Professors, university officials and top student delegates, all interested in metal casting. Phil Duke was the conference chairman this year, assisted by a committee made up of professors, former FEF students, and FEF Board Members.

Due to the generous "special contributions" of several companies and individuals (see back page), the **FEF Annual Banquet**, was held at the Adler Planetarium in Chicago on Thursday night, November 4. During the evening, several awards were presented including FEF's highest award, the **E.J. Walsh Award**. This award went to Professor Lifetime Patron, Douglas G. Warner of Porter Warner Industries. Also receiving special recognition were three magazines who have assisted FEF in its mission and goals this past year – FOUNDRY Management and Technology, Modern Casting, and Die Casting Engineer. The North American Die Casting Association, represented by Dan Twarog, made a $50,000 contribution to the FEF for NADCA's David Laine Scholarship Fund which is managed by FEF. Dave Sanders, this year's Vice Chairman, was the Master of Ceremonies.

During the General Session on Friday, November 5, the Keynote address was given by Linda Miller, Manufacturing Director-CFO-PTO, Ford Motor Co. This year's three panelists included Jerry Clancey, General Sales Manager, Fairmount Minerals, an FEF scholar from Kent State; Scott Strobl, Technical Director, Simpson Technologies, and attended Pittsburgh State; and Robert Smillie, Plant Manager-Cleveland Engine Plants at Ford Motor Co., current FEF Board Member and attended Western Michigan.

During the Edward C. Hoenicke Memorial Luncheon, FEF presented certificates of appreciation to Chuck Jones of the American Foundrymen's Society, in honor of his retirement and John Hough of the H.H. Harris Fund, for that fund's contributions to students. These men have been supporters of the need to help young people see this industry as an important life-long career choice and FEF commends them for their hard work over the years. A special AFS Director's Award was again given through FEF to one of the Key Professors. Doru Stefanescu from the University of Alabama was the recipient of this award.

The Industry Information Session offered students an up-close and personal look at the industry. It also gave the 50 participating companies the most cost-effective way to see some of the top metal casting students in the country all in one place.

The Awards and Recognition Breakfast speaker was the President of Southwest Texas State University, Jerome Supple. Following his comments, 21 sponsored scholarships were awarded to the student delegates who had submitted applications for these awards (see reverse side).

Bill Sorenson, FEF's Executive Director, announced next year's College Industry Conference, in Chicago on November 9-11, 2000. More information on this conference, or any of the FEF activities, can be obtained from the FEF office at 484 E. Northwest Highway, Des Plaines, IL 60016, Phone 847/2999-1776, Fax 847/299-1789, email info@fefoffice.org, Web page http://fefoffice.org.

1999 FEF COLLEGE INDUSTRY CONFERENCE

CIC Breakfast Awards, November 6, 1999

Scholarship	Name	School
Keith D. Millis Scholarship	Joshua Clabo	Tennessee Tech
Keith D. Millis Scholarship	Brandon Leatherberry	Wisconsin-Madison
Keith D. Millis Scholarship	Larry Piehl	Univ. Of Northern Iowa
Keith D. Millis Scholarship	Mike Brown	Alfred University
Ron Ruddle Memorial Scholarship	Oscar Suarez	Wisconsin-Madison
CISA Scholarship	Eric Hanson	Wisconsin-Platteville
AFS Southwestern Ohio Scholarship	Sarah Jordan	Ohio State
Richard M. Frazier Scholarship	Vernon Pocius	Penn State
William M. Grimes Schol. – Gartland Foundry	Erin Miller	Tri-State Univ.
Booth-Geo. W. Mathews Jr. Endowment	Eric Meyers	Southwest Texas State
Sanders-Geo. W. Mathews Jr. Endowment	Richard Ford	Missouri-Rolla
Witt-Geo. W. Mathews Jr. Endowment	Amy Hannigan	Penn State

James P. & Katherine Keating Scholarship	Eric Stemen	Michigan Tech
Ron & Glenn Birtwistle Mem. Scholarship	Craig Roberts	Cal Poly-San Luis Obispo
Ron & Glenn Birtwistle Mem. Scholarship	Marlon Gates	Kent State
Tony & Eldo Dorfmueller Scholarship	Joseph Cleveland	Purdue-West Lafayette
Wm. E. Conway Schol. – Fairmount Minerals	Boris Gavric	Univ. of Windsor
Deere Scholarship – Environmental	Michael Connal	Cal Poly-Pomona
Charles Marshall Scholarship	Curt deLeon	Cal Poly-Pomona
Johnstown Amer. Industries Scholarship (NEW)	Dan Dunaway	Bradley
Robert W. Reesman Mem. Scholarship	Guy Roush	Purdue-Indianapolis
Burleigh Jacobs Scholarship – Grede (NEW)	Todd Nichols	Wisconsin-Platteville
Donald G. Brunner Scholarship – Waupaca	Kandi Parsons	Wisconsin-Milwaukee
George Isaac Scholarship	Steven Sieffert	Kettering Univ.
Modern Casting Partners Scholarship	Laura Halley	Purdue-West Lafayette
Robert V. Wolf Mem. Scholarship (NEW)	David Carner	Missouri-Rolla

Special Mention

Jack H. Thompson Memorial Scholarship	Aaron Barklage	Missouri-Rolla
David Laine Scholarship	Don Carter	Kettering Univ.
	Timothy Dues	Tri-State Univ.
	Ian Murdell	Ohio State
	Matthew Pettus	Tri-State Univ.
	Gary Steffes	Wisconsin-Madison
	Grant Wesson	Univ. of Northern Iowa
	Jeremy Fink	Penn State
	Devin Hess	Missouri-Rolla
	Dirk Mooy	Missouri-Rolla

Companies and individuals contributing special gifts for the Annual Banquet at the Adler Planetarium:

Applied Process	Dwight Barnhard	Citation Corporation
Phil Duke	Fairmount Minerals	Foseco, Inc.
Inductotherm Corp.	NADCA	Porter Warner Industries
Dave Sanders	Rose Torielli	Waupaca Foundry

Henych Announces His Retirement

A letter to the Executive Director of the Ductile Iron Society

Dear Jack,

Fifty years ago I started my apprenticeship in a steel melting shop and during all those 50 years I enjoyed being part of the foundrymen's family. Even though feeling quite young – time has come to say farewell to my official business life, there are so many other interesting facets of life. They will certainly be my playgrounds for the years to come. Of course I will continue to follow-up the developments in the foundry industry. It's just impossible to stop after so many years!

I will retire on January 31st, 2000 (which is my last working day in the office) after 27 years with the Georg Fischer Foundries and 4 years with Georg Fischer Disa AG in Schaffhausen.

Let me take this occasion to thank you, as well as your colleagues whom I met during my professional life in your Company for the excellent co-operation, the interesting conversations and the support which I always experienced.

It was really a pleasure for me to have you not only as business partner, but also as a friend. We were certainly not always of the same opinion – but the discussions about problems gave both sides enough time to learn from each other and to find good compromises.

I would very much appreciate, if we could stay in contact in the future. You can use my email, fax or phone (phone/fax: +41-52-643 14 34, in USA (708) 58 59 171, i.henych@spectraweb.ch). I would always be pleased to hear from you and perhaps be able to help you with my experiences or my personal opinions.

I am sure that the Licensing Team of GFDE, which you know – H.J. Bohm, W. Hauke and Ms. U. Rochat – and probably new faces, will carry on the services which you know they have done during the past years and I would be very glad, if you would give them the same trust and support as you did for me.

I wish you, your family and your colleagues all the best and a lot of success in the new Millennium and remain,

with best regards,
yours truly,

I. Henych

William Beatty Obituary

William H. Beatty, of Yellow Springs, died Thursday, December 2, in his residence. He was 87 years of age.

Born June 18, 1912, in Twin Falls, Idaho, he was the son of E. Clyde and Lena (Wike) Beatty. He retired as vice-president from Morris Bean & Company and was an area farmer.

Bill was an original Ductile Iron board member and one of the signers of the DIS Articles of Incorporation in June, 1958. He served as the Society's president in 1970 and 1971.

Additional Information Resources

Additional information resources for the foundry industry

The new website of the CTIF (http://www.ctif.com)

At the time of great change (with the appearance of new information and communications technology) and major challenges (globalization of trade), it is necessary for all companies, and particularly small to medium-sized businesses in the foundry industry, to be constantly adding to their information resources in order to be best able to take on their competitors.

For this reason the CTIF has undertaken a huge project using the Internet in order to boost its information and support activities for the foundry trade.

Therefore, following on from the success of its initial website (opened over 3 years ago), the CTIF has embarked upon a project (now almost complete) aimed at progressively bringing its various information and technical support services ‘online’ on a website that has been redesigned for the occasion. In order to be able to guarantee users of the accuracy and validity of the information supplied, the data offered online has been carefully selected by the teams of the CTIF.

For the main part of its content, the site is available in both French and English.

Today, it can boast over 15,000 connections per week.

The main features of the site

1 - Presentation of the French foundry profession and its constituent companies

- **The organization of the foundry profession in France**
  The main bodies concerned are listed, most of which are directly accessible by Internet from the CTIF site.
- **Key statistical information**
  The site gives most of the results achieved by the French foundry profession including overall production, world ranking and distribution of product tonnage by business sector and by market segment etc.
- **The French foundries**
  A database containing information on all of the French foundries makes it possible to find a company not only through its company name or geographical location but also, for those having included the type of products they manufacture, by the types of alloy produced and/or by any casting processes used.

2 - Finding a supplier for the foundry sector

A database of suppliers of materials and products for foundries makes it possible to find a supplier by entering his company name of the description of one of his products.

3 - Keeping up-to-date with official standards in the foundry industry

The site introduces all of the official standards for the foundry trade (with the exception of hydraulics) including references, fields of application, precedence, and any possible variations with superseded documents.

Moreover, the database makes it possible to carry out a search by the major themes of the applicable standards (for example aluminium alloy, supply and inspection, etc.) The online availability of a "Standards News" service is being looked at. This service would provide information about the work and surveys currently underway.

4 - Introduction to the activities of the CTIF and the services it offers

All of the CTIF’s activities are introduced, including its surveys, training opportunities, design services, laboratory-related activities, strategic planning, certification, in-house diagnosis and advice for companies, as well as quality and environment-related activities. Certain research and development results with transfer possibilities are also available.

5 - A gateway to other "foundry" resources on the Internet

A range of hypertext links enables the surfer to pass directly from the CTIF site to those of the main bodies within the French foundry industry, and also to a certain number of others (selected by the CTIF) on an international level.

6 - Presentation of the basic technical documents distributed by **Editions Techniques des Industries de la Fonderie** (Foundry Industry Technical Publications)

Visitors will find a database making it possible to order and pay online, and including a presentation of all of the technical documents distributed by the E.T.I.F.

7 - Presentation and downloading of technical software

A range of technical foundry-related software, designed by the CTIF and likely to be useful to companies on a day-to-day basis (including fault diagnosis, item weight calculation, burden optimization, and calculation of feed and runner systems, etc.) is available, and may be downloaded from the CTIF sire to make evaluation easier.

8 - Database of translations of technical documents produced by the CTIF

Using a multi-criteria selection system, it is possible to search the library of translations produced by the CTIF to see if documents exist for a particular theme.

9 - Presentation of various certified reference materials.

The chemical compositions of all of the certified reference materials (produced by the CTIF) likely to be of interest to the foundry profession are to be found here.

10 - Gateway to the documentary library of the CTIF

The creation of a gateway to the documentary library of the CTIF is being looked at. It should make it possible to directly consult the bibliographical database of the CTIF on-line, (this being one of the most extensive to be found in the foundry field).

11 - Additional ways to contact the CTIF

The CTIF website offers additional means to directly contact the CTIF via electronic mail:

- Either via the central electronic mailbox of the CTIF inof@ctif.com
- Or by those of your usual contacts xxx@ctif.com

For all further information please contact:

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The website of the CTIF: http://www.ctif.com

NEWS BRIEFS

Meetings

The next meeting of the Ductile Iron Society will be held on **June 14-16, 2000** at the Hotel at Old Town in Wichita, Kansas. There will be a visit to Farrar Corporation in Norwich, Kansas. Call (440) 734-8040 or email the Ductile Iron Society jhall@ductile.org to make your reservations.

People

Intermet Names New General Manager of Havana Foundry

Troy, Michigan, September 29, 1999 – Intermet Corporation announced earlier this week that **Thomas E. Woehlke** will replace Brian Schlump as general manager of the Intermet Havana Foundry in Havana, Illinois.

James F. Mason, Intermet group vice president, said Woehlke will be in charge of plant operations in Havana. "Tom is a fourth generation foundryman who brings over 30 years of foundry management experience to Intermet," said Mason. "He’s a good hands-on manager with a commitment to the industry."

Woehlke began his career at Grede Foundries, and later spent five years as vice president of manufacturing as Wells Manufacturing in Skokie, Illinois. Most recently he was the president and partner at Lawran Foundry Company of Wisconsin. He has also held a variety of positions with the American Foundrymen’s Society, serving as its president from 1994 to 1995.

Woehlke earned a B.S. degree in industrial engineering and engineering operations from Iowa State University. He served in the U.S. Navy from 1968 to 1971.

With headquarters in Troy, Michigan, Intermet Corporation and its subsidiaries design and manufacture precision iron and aluminum cast components for automotive and industrial equipment manufacturers worldwide. Intermet also produces precision-machines components and manufactures cranes and specialty service vehicles. The company has more than 7,000 employees at 19 operating locations in North America and Europe. Intermet’s internet address is www.intermet.com.

People

Chicago (Oct. 7, 1999) – **Louis Bruno** has joined Superior Graphite Co. As Marketing specialist, company officials have announced.

In his new position, Bruno is responsible for overall marketing support, including market research and analysis, and Web development. He is responsible for developing, implementing and managing business plans and market strategies for all SGC product lines on a global basis.

"I look forward to applying my education to SGC’s corporate marketing program," Bruno said.

Bruno, who took over the position June 14, graduated from Marquette University in Milwaukee in May, receiving bachelor’s degrees in international business and marketing.

People

Milwaukee, Wisconsin – Grede Foundries, Inc., has named **David Roycraft** as the Works Manager of its New Castle foundry in New Castle, Indiana.

Roycraft received a B.S. in Metallurgy from Purdue University and an M.B.A. from Indiana University. He joined the New Castle foundry in February of 1999 as Factory Manager.

Purchased in 1989, the New Castle foundry produces ductile iron castings for the automotive industry. Grede Foundries operates 12 foundries in the U.S. and the U.K., and is a recognized leading producer of high quality castings in gray iron, ductile iron, and steel.

Business

Intermet Acquires Leading Automotive Suppliers; Major Boost to Aluminum Manufacturing Capability
Troy, Michigan, November 17, 1999 – Intermet Corporation announced today that it has entered into a definitive agreement with JJM, LLC, Gantec II, LLC, and Cerberus Institutional Partners, L.P., to purchase Ganton Technologies, Inc., and Diversified Diemakers, Inc. Ganton Technologies is a Wisconsin-based supplier of die-cast aluminum components to the automotive industry. Diversified Diemakers, with headquarters in Missouri, is a leading manufacturer of magnesium die-cast automotive components. Combined, the two companies employ 2,000 people and are expected to have sales of $235 million in 1999. Terms of the agreement were not released.

Ganton Technologies is one of North America's largest aluminum die casters. Automotive fluid-handling components, such as oil pans, transmission housings and cam covers, make up about 65% of the company's overall business, with brackets and structural components representing the balance. Ganton Technologies operates three manufacturing facilities, two located in Wisconsin and one in Tennessee. Ganton also operates an engineering center in Wisconsin.

Diversified Diemakers specializes in complex, highly-engineered thin-wall, magnesium diecast products such as brake pedal brackets, instrument panel frames and multi-slide housings representing significant offerings to the automotive, commercial and electronics industries. Diversified Diemakers has three production facilities and a product development center, all in Missouri.

Intermet Chairman and Chief Executive Officer John Doddridge said, "We are particularly pleased to acquire both Ganton and Diversified Diemakers. We consider them well managed, with world-class plants. The combination significantly builds on Intermet's strategy of being a leading, full-service metal caster, primarily serving the automotive industry.

"With the acquisition, we anticipate approximately $1.3 billion in sales in fiscal 2000, assuming the economy remains strong," said Doddridge. "The addition of Ganton/Diemakers to Intermet's existing aluminum and zinc casting capabilities is expected to provide a total of almost $400 million in non-ferrous casting sales next year. We anticipate that next year's revenues will be approximately 61% iron, 20% aluminum, 9% magnesium, 2% zinc, and 8% other."

Doddridge emphasized that the acquisition is not a move away from ferrous castings, but a broadening of materials and casting processes consistent with Intermet's strategy. "We plan to continue the company's growth in ferrous castings," he added.

Joyce Johnson-Miller, chairperson of Ganton/Diemakers, said "We have made substantial progress with Ganton Technologies over the past four years and most recently with Diversified Diemakers. Our companies have a talented workforce and leadership position in the markets where we compete. I am confident that both companies, as part of Intermet, will continue to grow and become even stronger within the industry."

Doretha Christoph, Intermet's chief financial officer, said, "We expect the acquisition to be accretive in the year 2000 and anticipate closing this transaction by mid-December." The acquisition is subject to certain regulatory approvals.

With headquarters in Troy, Michigan, Intermet Corporation and its subsidiaries are full-service suppliers to the automotive and industrial equipment industries worldwide, providing precision iron and aluminum cast and finished components. Intermet also manufactures cranes and specialty service vehicles. The company has more than 7,000 employees at 19 locations in North America and Europe. More information bout the company is available on the internet at www.intermet.com.

This news release may include forecasts and forward-looking statements about Intermet, its industry and the markets in which it operates. Forward-looking statements and the achievement of any forecasts or projections are subject to risks, uncertainties and other factors that could cause actual results to differ materially from those expressed or denied. Such risks and uncertainties are fully detailed as a preface to the Management's Discussion and Analysis of Financial Condition in the Company's 1998 Annual Report for the year ended December 31, 1998.

Business

Tupy of Brazil moves into CGI with SinterCast
An agreement has been signed between Fundicao Tupy of Brazil and SinterCast AB (publ) of Sweden signaling the first South American foundry entering into production preparation for Compacted Graphite Iron (CGI) for engine components to the automotive

industry using the Swedish SinterCast Foundry Process Control Technology.

Tupy, which is the largest independent foundry in Latin America, has foundries in Joinville and Sao Paulo with a combined capacity of 380,000 tons per year of iron for automotive components for the South and North American automotive and engine industry as well as for European customers.

Among Tupy's customers are Cummins, Navistar, Detroit Diesel, Mercedes Benz, Volkswagen, Pengeot, Perkins and Iveco.

A SinterCast System 2000 will be shipped this year and installed in Joinville early spring next year.

SinterCast is a Swedish company, noted on the Stockholm Stock Exchange, specializing in the development, manufacturing and sales of its world leading process control technology for high volume production of CGI components, especially engine blocks and cylinder heads.

Among SinterCast's customers and end-users are Allen Power Engineering (part of the Rolls Royce Group), Caterpillar, Audi and the independent foundries Halberg in Germany, Sakana in Spain, VDP in Italy and Cifunsa in Mexico.

This press release is issued simultaneously by Tupy in Brazil and SinterCast in Sweden.

Stockholm, 18 November 1999
SinterCast AB (publ)

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Business

Foseco, Corning Donations Support Case Western Reserve University Metal Casting Laboratories

(Cleveland, November 9, 1999) Foseco, Inc., a leading provider of proprietary products and systems that enhance quality and efficiency in aluminum, iron and steel foundries, and Corning Inc., leaders in materials technology, each recently donated $5,000 for the renovation of metal casting laboratories at Case Western Reserve University. The laboratories serve as a focal point for metal casting research and teaching activities at the university.

The mission of the Case Metal Casting Laboratories (CMCL) is to support the foundry and metal casting education casting education programs at Case Western University, to conduct long-term graduate student-oriented research, and to provide facilities and resources for industry-supported projects. Andrew Adams, Foseco product application manager, noted, "Collaboration and close ties with industry are vital for the future of foundry industry education and research." Adams is also a member of the university's industrial advisory committee.

David Naylor, Corning product line manager, said, "These facilities will serve a vital role in providing training for the next generation of engineers and scientists who are essential to the metal processing and manufacturing industry. We are proud to offer our support."

Business

Certification Announcement

Livonia, Michigan – Applied Process, Inc. a leader in austempering heat treating technology is proud to announce certification of its new AP Southridge plant in Elizabethtown, Kentucky for ISO9002 and QS9000. It now joins the other Applied Process plants in Livonia, Michigan and Oshkosh, Wisconsin with that designation.

The certification was achieved only 9 months after the new facility opened. Mel Ostrander is president of the facility.

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Business

Burmah Castrol Announces Sale of Aluminum Smelter Group
Cleveland, October 11, 1999 – Burmah Castrol has announced the sale of its aluminum smelter products business to Pyrotek Inc. of Spokane, Washington, as part of the company's strategy to expand in core chemical businesses serving the foundry, steel, printing, releasants, mining and investment casting industries.

Burmah Castrol is best known in the foundry industry as the parent company of Foseco, a leading provider of proprietary products and systems designed to enhance quality and efficiency in aluminum, iron and steel foundries.

According to Roger Stanbridge, CEO of Foseco, Americas, "The sale of Burmah Castrol's aluminum smelter products group is part of the company's strategy to focus on strengthening its principle businesses while divesting businesses that do not fit its particular skills. The needs of aluminum cathouses are significantly different from the needs of aluminum, iron and steel foundries. Foseco has been well-known in the foundry industry for many years and will continue its traditions of innovation and service to this industry."

Foseco will continue to market SIVEX® FC foundry filters, DYCOTE® refractory coatings, TILITE® grain refiners, COVERAL® aluminum fluxes, Rotary Degassing Units (MDUs/FDUs), as well as KALMIN® and TEMPGARD® feeding systems to aluminum and other non-ferrous foundries.

A subsidiary of Burmah Castrol PLC's Chemicals Group, Foseco operated in over 100 countries around the world, with headquarters for the American region in Cleveland, Ohio. Through its dedication to research, Foseco is credited for numerous advancements in metal casting since its founding in 1932.

Business

Intermet Reports Record Third Quarter Sales
TROY, MICHIGAN, October 14, 1999 -- Intermet Corporation (Nasdaq: INMT) today reported net third-quarter sales of $225 million, setting a record for sales in any third quarter in Intermet's history. Third-quarter sales in 1999 increased $36.5 million compared with the same period last year. This increase is partially the result of strong domestic and European light truck markets and $20 million of the increase is due to two acquisitions made at the end of 1998.

Third-quarter income was $0.29 per diluted share on net income of $7.4 million compared with $0.36 per diluted share on net income of $9.3 million in the third quarter of 1998. Earnings were in line with analysts' expectations.

John Doddridge, chairman and chief executive officer, said, "The exceptionally robust economy has us operating at maximum capacity as we strive to meet customer demand. This has caused a substantial increase in our operating costs. The outlook is positive, however, as we continue to add capacity to provide relief to our plant operations." Doddridge noted that 25,000 tons of capacity has been added at one foundry with an additional 50,000 to 60,000 tons to come online at another plant by the end of the year.

"Intermet has very strong product content in the light truck market, the one area that has seen tremendous growth in the past few years," said Doddridge. "The auto manufacturers are converting many of their car plants to truck facilities and we are working extremely hard to meet those changing needs."

Record sales and earnings continued for the first nine months of 1999 as Intermet posted year-to-date sales of $716 million and earnings of $36.2 million ($1.41 per diluted share). Sales for the first nine months of 1999 were up $83.6 million from 1998 nine-month sales of $633 million, and net earnings were up $3.3 million from $32.9 million in 1998 ($1.27 per diluted share). 1999 sales year-to-date reflect exceptionally strong domestic and European light truck markets with earnings reflecting a one-time tax benefit of $0.18 per diluted share in the second quarter.

The Intermet board of directors voted to approve a quarterly dividend of 4 cents per share, payable December 30, 1999, to shareholders of record as of December 1, 1999.

With headquarters in Troy, Michigan, Intermet Corporation and its subsidiaries design and manufacture precision iron and aluminum cast components for automotive and industrial equipment manufacturers worldwide. Intermet also produces precision-machined components and manufactures cranes and specialty service vehicles. The company has more than 7,000 employees at 19 locations in North America and Europe. The company's Internet address is www.intermet.com.

This news release may include forecasts and forward-looking statements about Intermet, its industry and the markets in which it operates. Forward-looking statements and the achievement of any forecasts or projections are subject to risks, uncertainties and other factors that could cause actual results to differ materially from those expressed or denied. Such risks and uncertainties are fully detailed as a preface to the Management's Discussion and Analysis of Financial Condition in the Company's 1998 Annual Report for the year ended December 31, 1998.

Business

Intermet to Close Ironton Iron Foundry - Cites Loss of Business
TROY, MICHIGAN, December 7, 1999 -- Intermet Corporation (Nasdaq: INMT) today announced plans to permanently close its Ironton Iron, Inc., foundry in Ironton, Ohio.

The foundry is expected to lose most of its remaining business in early 2000 as customers move work to other suppliers. The Ironton Iron facility has had consistent and enduring financial losses. Given the expected steep decline in business, company officials expected losses for the foreseeable future. In addition, the foundry is one of Intermet's oldest facilities and the cost of modernization would have further impacted already weak operating results.

Intermet purchased Ironton Iron, Inc., in 1988. Prior to that the facility operated for about two years under employee ownership.

The plant manufactures cast ductile iron parts for automotive customers, principally for use in domestically produced light vehicles. It has an annual casting capacity of 98,000 tons, but is currently operating at about 50 percent capacity. The foundry employs approximately 600 people, including hourly and salaried staff. Hourly employees at the plant are represented by the United Steelworkers of America Local 3664.

Intermet anticipates that the foundry will be closed in the first quarter of 2000; however, the actual date has not been determined. Company representatives are meeting with the union and other affected employees to discuss this action and its effects on the workers.

"The decision to close the Ironton foundry was an extremely difficult one for us," said James F. Mason, group vice president for Intermet. "Intermet has been working for years to make this plant efficient. We invested over $100 million in the plant and lost every penny of it, and more. We feel that all avenues were explored, but unfortunately, the loss of business dictated the eventual outcome of our efforts."

Imtermet expects a pretax charge of $16-18 million in the fourth quarter of 1999 as a result of the shutdown.

Associate Member Profile

AP Southridge Inc.

201 Altec Drive, PO Box 2309
Elizabethtown, KY 42702-2309

Applied Process Inc. was incorporated in 1984 as a division of Atmosphere Group Inc. Its mission, was to commercialize the Austempering of larger components, especially castings and forgings. The company grew rapidly and in 1996 moved to its current location in Livonia, Michigan. In 1994 Applied Process became a "stand alone" company with John Keough as President and CEO. Applied Process added a technical licensee in Australia; ADI Engineering. As demand grew, particularly for Austempered Ductile Iron (ADI), a second facility was added in Oshkosh, Wisconsin. That company, AP Westshore Inc. started operation in 1995. A British licensee, ADI Treatments was added in 1996. As North American ADI applications topped 50,000 tons per year it became apparent that a third facility would be required. These are the origins of AP Southridge Inc.

After breaking ground in August of 1998, AP Southridge opened for business in January of 1999. The latest, in the Applied Process family of companies, AP Southridge is a 38,000 square foot facility incorporating the latest in Austempering technologies. Designed to address the growing Austempering needs of customers in the Midwest, Southeast and mid-South, the plant is located at the intersection of Interstate 65 and the Kentucky Parkways. The plant currently operates 24 hours per day, seven days per week, with two, independent Austempering lines. The facility's maximum design capacity is five lines, (or 50 tons of Austemper processing per day).

AP Southridge is designed to be a fully automated, environmentally friendly facility. It employs updated versions of the batch Austempering systems that have been developed and enhanced at AP facilities in Wisconsin and Michigan. These systems are more labor, and energy efficient than conventional heat treatment systems. Additionally, the new facility requires NO waste water permit: a significant development for the heat treat industry. The process is controlled and monitored by an edge-of-the-art computer process control system that is bar code driven, user configurable and fully data based. The quenchant, a mixture of molten nitrite and nitrate salts, is 100% reclaimed and recycled.

AP Southridge is fully supported by the Applied Process Inc. Technologies Division in research, marketing and administration. AP maintains a full time, fully funded internal research and development effort that assesses better, faster, and more cost effective ways of processing materials. Additionally, AP's staff specializes in technical marketing; directly assisting the customer in their sales efforts.

The Austempering process includes Austempered Ductile Iron (ADI), Austempered Gray Iron (AGI), and Austempered and Carbo-AustemperedÔ steels. The Austempering process produces ferrous components that are (in many cases) stronger, tougher, lighter, quieter and more wear resistant than other conventional material/process combinations. The ADI process in particular has created opportunities for ductile iron foundries to compete with forged steels for material strength and aluminum for component weight.

The AP Southridge team achieved QS9000 certification within 10 months of start-up and is currently servicing customers in the foundry, forging, stamping and machining industries. They specialize in ADI and can help you convert aluminum and steel forgings and castings to high performance ADI. President Mel Ostrander and his crew stand ready to serve you. Give them a call at 270-234-0404 or visit them at www.appliedprocess.com for all of your Austempering needs.